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Missouri Medicine
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In publication since 1904, *Missouri Medicine: The Journal of the Missouri State Medical Association (Missouri Medicine)* was created to educate and contribute to the art and science of medicine in Missouri, the United States, and globally. Clinical and scientific articles are peer-reviewed through the *Missouri Medicine's* distinguished Editorial Board. Perspectives, opinion submissions, and feature articles are reviewed for originality, content, purpose, and relevance to clinical medicine. Instructions for Authors/Submissions are clearly stated, well-defined, and rigorously followed. Readers include physicians, physicians-in-training, researchers, and ancillary healthcare providers. *Missouri Medicine* receives submissions from across the United States and many countries world-wide. *Missouri Medicine* is ranked among the top three state medical journals.

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- Corrections are published when deemed necessary
- Feedback and correspondence is encouraged

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AI as Draftsperson, Human as Architect—Reframing Medical Authorship

by John C. Hagan III, MD

I want to give my co-author gemini.ai full credit for the time I saved and the enhanced and improved content. Let's 'get real' about AI use and disclosure.

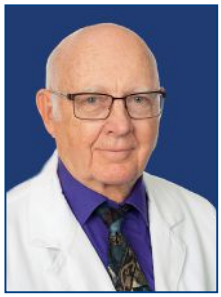
Pardon me for a moment of professional candor: I consider myself a more than capable writer. Having taken numerous courses in exposition and technical writing, and having edited two medical journals and two medical textbooks, I know firsthand that masterly writing is demanding, skill-intensive, and experience-dependent. A typical editorial for Missouri Medicine requires four to six hours of literature review, outlining, drafting, and painstaking revisions.

This editorial—which I consider among my finest—was written in collaboration with Gemini, an artificial intelligence (AI) tool. Acting as a research partner and draftsperson, AI saved me roughly four hours of labor while yielding a manuscript of noticeably higher clarity, structure, and depth than I could have produced alone. AI by itself could not produce a suitable editorial; to optimize AI it must be partnered with a knowledgeable human. Would you like to save valuable time, elevate the quality of your scientific writing, and reclaim extra hours for your family, your patients, and yourself? Of course you would. If so, read on. You need an AI partner.

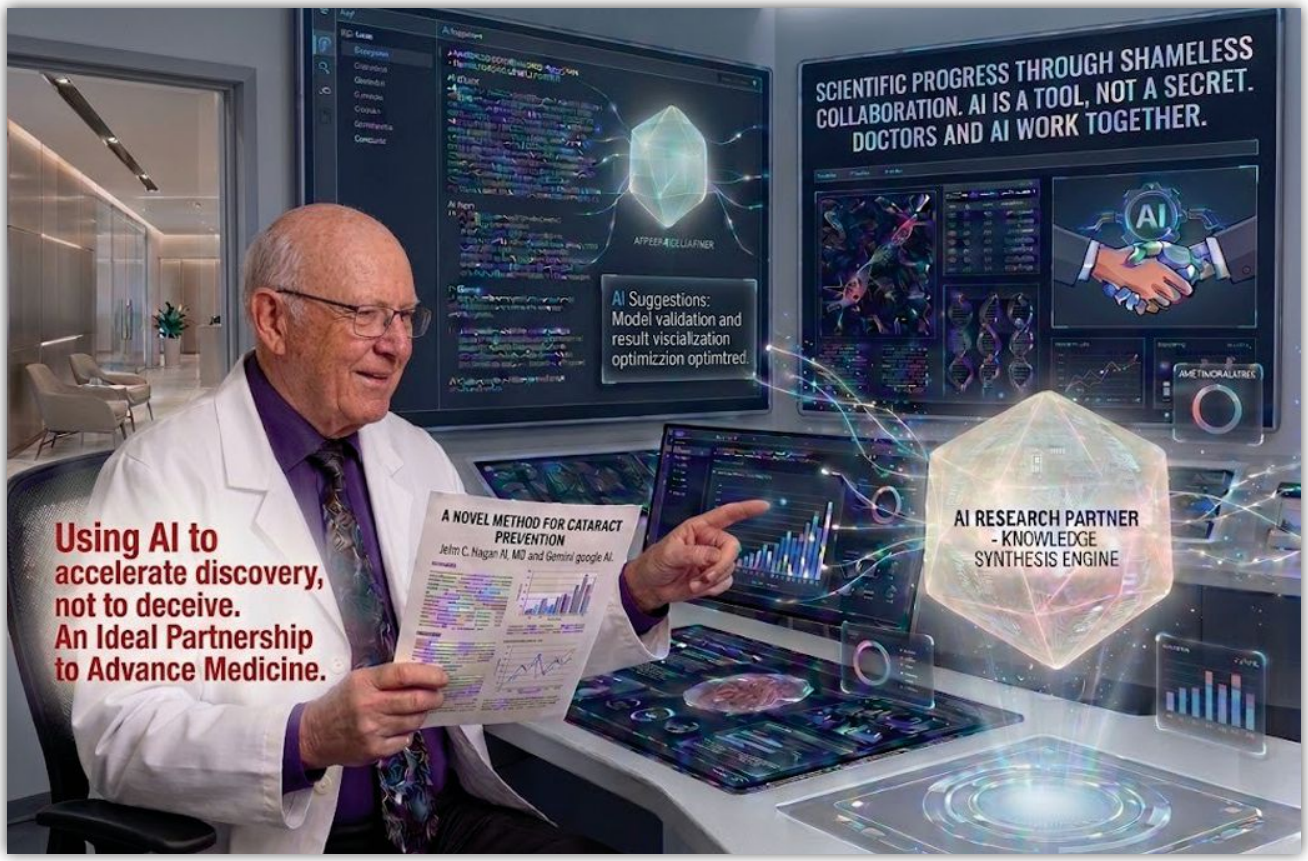
The biomedical publishing ecosystem is undergoing an unprecedented structural shift driven by Large Language Models (LLMs) and generative artificial intelligence. In response to ChatGPT, Claude, Gemini, and specialized medical drafting platforms, major editorial bodies—including the International Committee of Medical Journal Editors (ICMJE)[1] and the Committee on Publication Ethics (COPE)[2]—have established strict protocols regarding artificial intelligence. The prevailing policy mandates formal disclosure, requiring authors to declare whether, where, and how AI tools were employed during manuscript preparation.[1,2]

Mandatory disclosure is unenforceable and masks a deeper reality. Medical journals should permit generative AI in article preparation with or without explicit disclosure. Generative AI handles the mechanical tasks of literature synthesis, initial drafting, and structural organization with superior speed and remarkable clarity. The essence of scientific authorship has never been mechanical word production; it is the rigorous verification, ethical oversight, clinical contextualization, intelligent human insight, and final editorial control over the published text.[1,2]

Attempting to police text generation through disclosure logs or detection software misdiagnoses generative technology. By examining empirical data on AI usage, the breakdown of automated detection



John C. Hagan, III, MD, is Past President of the Kansas City Medical Society, the Missouri Society of Eye Physicians & Surgeons and the Clay-Platte County Medical Society. He is Editor of *Missouri Medicine* and a Contributing Editor to *Kansas City Medicine*. Dr. Hagan is an ophthalmologist, author, and researcher in Kansas City, Missouri USA. Learn more at www.msma.org/MoMed-Editor.



software, the historical integration of handheld calculators in mathematics, and the realities of clinical liability, it becomes clear that medical publishing must move past the disclosure illusion and re-anchor validity strictly on human accountability.

The Illusions of Mandatory Disclosure in Biomedical Literature

Recent cross-sectional analyses of manuscript submissions across peer-reviewed journals reveal a stark discrepancy between declared and actual AI usage. Research evaluating empirical submissions to biomedical journals showed self-reported AI disclosure rates hovering at a modest 3% to 6%.[3] The vast majority of these disclosures cited low-level rote applications, such as refining prose, correcting grammar, or translating non-native drafting.[3]

Independent computational analyses portray a dramatically different picture. Large-scale linguistic surveys analyzing tens of millions of PubMed abstracts reveal unprecedented spikes in vocabulary and syntactic structures unique to LLMs.[4,5] Computational linguists estimate that at least 13.5% to over 20% of all biomedical abstracts now bear hallmarks of generative AI drafting.[4,5] Anonymous surveys of active academic researchers suggest the true figure of AI assistance—spanning literature gathering, code generation, and initial drafting—ranges from 30% to over 70%.[6,7]

This gap between formal self-reporting and empirical reality highlights a systemic policy failure. Mandatory disclosure requirements create an unavoidable self-selection bias and impose an unfair "transparency penalty." There should not be a penalty for being honest. Scholars who faithfully declare AI use frequently encounter unconscious bias from peer reviewers and editors, who systematically rate disclosed manuscripts as less novel or rigorous regardless of the underlying data quality. Consequently, a compliant minority submit declarations for basic grammar editing, while a silent majority utilizing AI for substantive drafting omits disclosures to avoid reputational stigma, ambiguous guidelines, or the practical impossibility of defining where basic digital assistance ends and generative AI begins.[3,6]

When a clinician uses an AI tool to summarize 20 clinical trials, draft a background review, rephrase

a methodology section, or fix passive voice, at what exact threshold does disclosure become appropriately mandatory? The boundaries are intrinsically porous. Modern word processors embed language models into spellcheck, autocompletion, and reference formatting. Mandating that authors catalog every prompt and iteration is as illogical as asking a researcher to disclose every internet search query while drafting a manuscript.

Speed, Voice, and the Corrective Human Layer

Scientific literature is not poetry; it is a vehicle for the precise, unambiguous transfer of empirical data, clinical observations, and human intellectual conclusions. Generative AI excels at the labor-intensive mechanics of scientific communication, including synthesizing hundreds of pages of background literature into cohesive contextual summaries in seconds, organizing raw experimental data into standardized IMRAD (Introduction, Methods, Results, and Discussion) structures, and leveling the playing field for non-native English-speaking clinicians whose research has historically faced higher rejection rates due to prose mechanics rather than scientific merit.[8]

Critics frequently caution that language models are prone to hallucinations, such as fabricating citations, misinterpreting statistical nuances, or introducing factual errors.[9] Beyond discrete factual inaccuracies, generative systems demonstrate a structural inclination toward statistical centrality, thereby fostering a mode of discourse that risks stylistic and conceptual homogenization. Such convergence can attenuate fine-grained clinical discriminations and marginalize low-frequency, hypothesis-driven edge cases that are essential to rigorous inquiry.

Critics misunderstand the distribution of labor in modern scientific workflows. AI is not the author; it is the draftsperson. The human author remains the architect whose responsibility is to review every line, audit every cited reference, correct algorithmic hallucinations, reverse algorithmic flattening to restore nuanced clinical voice, and ensure strict alignment with experimental results.[1,2] Unlike a deterministic pocket calculator, which reliably yields identical arithmetic results, a probabilistic language model generates statistical approximations that can invent plausible falsehoods. That fundamental distinction is precisely why human accountability cannot be delegated: the unpredictability of the tool demands that the author act not merely as a passive reader, but as an aggressive auditor who interrogates every citation and claim before certifying the manuscript.

When an AI-assisted manuscript contains a factual error or a fabricated claim, the fault lies entirely with the human authors who signed the manuscript submission form, not the tool used to generate the prose.[1,2] By shifting the focus away from how the text was generated and back to whether the published claims are true and reproducible, journals reinforce the fundamental tenets of scientific accountability. Whether an author wrote a paragraph manually over three hours or edited an AI-generated paragraph in five minutes is immaterial to the clinical reader. What matters is that the paragraph is accurate, clear, and verified.

Educational Parallels: The Failure of Detection and Take-Home Essays

The dynamics unfolding in medical journals mirror the crisis across K–12 and higher education. For decades, the long-form essay served as the primary proxy for measuring critical thought, comprehension, and analytical depth. Generative AI has permanently disrupted this paradigm across every tier of education.

According to national survey data from the Pew Research Center, roughly 20% of middle school students (grades 7–8) report using generative chatbots for coursework.[12] Adoption accelerates in secondary education, rising to 31% among 11th and 12th graders.[12] At the university level, the Lumina Foundation and Gallup report that 57% of enrolled college undergraduates use generative AI in their academic work.[10] Furthermore, multiple academic surveys indicate that the overwhelming majority of students who utilize AI for coursework do not disclose that assistance to instructors.[11,13] The use of AI in education and research is accelerating toward universal adoption.

Educational institutions have attempted to curb this trend through explicit bans and automated AI detection software, both of which have proven disastrously ineffective. Automated AI detectors rely on statistical measures of language perplexity and burstiness (the variation in sentence length

Generative AI is not a fleeting trend, nor is it an existential threat to intellectual integrity. It is an extraordinary cognitive amplifier.

and structure). Extensive peer-reviewed computer science literature demonstrates that these tools are fundamentally unreliable.[14,15] On one hand, it is remarkably easy for a knowledgeable person to manipulate prompts, introduce deliberate stylistic variance, or run text through basic paraphrasers to generate false negatives that completely disguise AI-generated prose.[15] On the other hand, innocent human authors inadvertently trigger false positives simply by employing formal, structured, or highly formulaic phrasing—a flaw that disproportionately penalizes non-native English speakers.[14] Because detection software produces both false security and unjust accusations, using probabilistic tools to police prose creates untenable legal and ethical liabilities for academic institutions.[13,14]

Because AI usage is ubiquitous and undetectable, grading students on unsupervised prose generation completed at home is no longer a viable method for measuring intellectual capability. In an era where any student can generate a polished analysis of a clinical trial or drug mechanism in seconds, grading prose evaluates software efficiency rather than student mastery. A necessary distinction must be drawn between the expert practitioner and the apprentice scholar. For the experienced clinician, AI serves as an efficiency amplifier for mechanical tasks; for the novice student, cognitive offloading risks preempting the foundational acquisition of critical reasoning. Yet the remedy for novice learning is not to demand unenforceable disclosures on unsupervised assignments, but to structure academic evaluation around interactive, real-time demonstrations of understanding—such as live defense, oral examination, collaborative problem-solving, and direct synoptic evaluation—where external digital crutches cannot substitute for personal mastery.

Historical Echoes: The Hand Calculator Analogy

The current anxiety surrounding generative AI in publishing and education echoes the fierce opposition that accompanied the widespread adoption of electronic handheld calculators in the 1970s and 1980s. When affordable scientific calculators entered the market, educators and academics reacted with alarm. School boards banned calculators from classrooms, arguing that students would lose basic arithmetic capabilities, conceptual understanding would be replaced by mechanical button-pushing, and standardized testing would become meaningless if calculations could be performed instantly.[16]

For years, intense debates raged over whether students should be permitted to use calculators on exams, whether their use constituted cheating, and whether calculator usage ought to be explicitly restricted or disclosed on student educational efforts.[16] Over time, this resistance collapsed under the weight of technological reality. As calculation tools became ubiquitous across engineering, scientific research, and everyday life, educators realized that forcing students to perform long division by hand was an inefficient use of cognitive bandwidth. While modern students may perform mental arithmetic less rapidly than their peers in the analog era, the integration of calculators permitted mathematics curricula to shift upward toward higher-order calculus, linear algebra, statistical modeling, and conceptual problem-solving.[16]

Generative AI is the syntax calculator for prose and research synthesis. Just as ubiquitous computing shifted the focus of mathematics from basic calculation to higher-level quantitative reasoning, generative AI shifts the focus of scholarly publishing from raw sentence construction to higher-order critical evaluation, synthesis, and clinical verification. Fearing that clinicians or researchers will forget how to write ignores the reality that writing is simply a medium for thought. When the mechanical burden of prose generation is reduced, human cognitive capacity is freed to focus on truth, logic, original thinking, patient care, and clinical research.

Linguistic Parity, Peer Review, and Legal Realities

Beyond pedagogical alignment, permitting AI in medical publishing regardless of explicit disclosure addresses critical structural imperatives in the scientific ecosystem: First, unrestricted AI adoption directly advances linguistic parity across global medicine by dismantling historic language barriers. For decades, international clinicians and researchers from non-English-speaking regions have faced disproportionate rejection rates, prolonged peer-review delays, and exorbitant translation costs prior to submission.[8] When journals enforce strict disclosure declarations for basic linguistic polishing or structural drafting, they impose a subtle double penalty on non-native English scholars. Allowing authors to freely leverage AI drafting assistants establishes a fair, merit-based baseline, ensuring that breakthrough clinical trials from South America, Africa, Asia, or other regions are evaluated strictly on their scientific rigor and methodological validity rather than their adherence to Western prose conventions.[8]

Second, reliance on automated AI detection software represents a technical and ethical dead end for journal editorial boards. Because knowledgeable users can easily produce false negatives to disguise AI origin while innocent, highly structured human writing continuously triggers false positives, software detection is intrinsically unworkable as an enforcement mechanism.[14,15] When journals mandate disclosure logs without possessing reliable tools to verify compliance, they establish an asymmetrical system that penalizes honest authors while failing to catch authors who deliberately obfuscate their use of AI. Using flawed probabilistic software to flag or reject submissions exposes editorial boards to severe ethical and reputational risks.[13,14]

Third, editorial policies must realign with pragmatic workflow norms across the entire publishing continuum. Medical journals are currently operating under a self-contradictory standard, attempting to police authorial AI use while simultaneously confronting severe peer-reviewer and clinical physician shortages. In practice, peer reviewers and editors frequently utilize language models to summarize long submissions, cross-check references, or structure editorial feedback. Enforcing strict disclosure rules on authors while reviewers utilize digital assistance creates an untenable double standard. Some argue that disclosure logs are necessary to signal to peer reviewers which sections warrant closer scrutiny. Yet treating AI disclosure as a triage flag encourages dangerous editorial complacency; it invites reviewers to audit disclosed manuscripts while granting an unearned presumption of accuracy to undisclosed or manually drafted submissions. Human error, cognitive bias, and literature mischaracterization have plagued medical publishing for centuries. Rigorous peer review requires scrutinizing the veracity of data and citations across every manuscript, irrespective of how the prose was generated.

Finally, current legal frameworks across international copyright bodies uniformly hold that AI algorithms cannot be listed as legal authors because machines cannot hold legal liability or copyright ownership.[1,2,17] Permitting AI usage with or without disclosure maintains this legal clarity. Equating algorithmic drafting with traditional ghostwriting misconstrues both practices. Commercial ghostwriting was banned because undisclosed corporate entities with financial conflicts of interest manipulated scientific narratives behind an academic facade. Generative software harbors no corporate agenda, financial conflicts, or authorial agency. It is an instrument wielded entirely by the designated human author, who remains exclusively liable for every word and concept in the published work.

It is equally crucial to distinguish manuscript text generation from patient data confidentiality and institutional review board (IRB) compliance; entering protected health information into public LLMs constitutes a severe regulatory breach, but that is a data privacy governance issue rather than an authorial disclosure mandate. The human authors listed on the manuscript's title page assume total legal, ethical, and scientific liability for both data security and content validity.[1,2] If an article contains plagiarized data, falsified figures, or fatal methodological flaws, the human authors are fully accountable regardless of what digital tools were used during drafting.

A Call for Pragmatic Realism

Medical journals and educational institutions must abandon the punitive and ineffective policy

of hunting for undisclosed AI usage. The "with disclosure" compromise currently favored by publishers is merely a temporary transition phase that offers a false sense of control while failing to address the realities of modern text generation. Publishers and academic leaders should adopt a policy grounded in pragmatic realism: medical journals should permit AI unconditionally. Authors should be free to use AI tools for drafting, editing, synthesizing, and structuring manuscripts without mandatory disclosure declarations, provided that all published content is accurate, reproducible, and fully verified by human authors. Editorial boards and peer reviewers should allocate resources toward validating clinical data, auditing statistical methods, and ensuring experimental reproducibility rather than attempting to police sentence origin. Secondary and higher education must discontinue the practice of using unsupervised long-form take-home essays as a primary measure of student intellect, evolving instead toward live defense, oral examination, collaborative analysis, and real-time critical thinking. Generative AI is not a fleeting trend, nor is it an existential threat to intellectual integrity. It is an extraordinary cognitive amplifier. By shedding the illusion of mandatory disclosure and embracing human accountability as the sole metric of scientific and educational validity, we can build an academic system that is faster, more equitable in access, and focused on genuine clinical and intellectual achievement.

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Disclosure

Google Gemini AI was used extensively in preparing this article. It resulted in a more thoughtful, complete nuanced content and saved me four to five hours which at my age is greatly appreciated.

MM

Denied by Algorithm: How AI Has Accelerated Health Insurance Rejections

by Kevin D. Weikart, MD

When a patient receives a claim denial or rejected prior authorization, they often envision a qualified medical reviewer carefully reading through their chart and reaching a thoughtful decision.

Now in the United States, major insurers are increasingly initiating artificial intelligence (AI) models and automated algorithms to batch-process millions of medical claims and coverage requests. Insurers then market these algorithms as tools for administrative efficiency and speed. This has resulted in there is a wave of investigative reports, class-action lawsuits, and regulatory inquiries reveal a harsher reality: technology is now being deployed to streamline denials on a massive scale, which maybe overriding the judgment of treating physicians.

The Speed-over-Care-Model

Algorithms in action automated denial tools depend on predictive models, data matching, and rigid data sets rather than individualized patient evaluation. By automating the initial screening phases, algorithms can instantly flag claims that deviate even slightly from pre-programmed coverage guidelines. Two notable cases have highlighted how this technology functions in practice.

Batch-Processing

Systems, the National Insurance Company algorithm, flag discrepancies between a patient's diagnosis and an insurer's preset list of approved test or treatments. A ProPublica investigation revealed that during a two-month period in 2022, the insurance company used PxDx to reject more than 300,000 claims, averaging approximately 1.2 seconds per claim. Medical directors were reported to sign off on batches of tens of thousands of denials without ever opening each individual patient file.

Traditional vs Algorithmic Review

Traditional Review

[Patient claim] --- [Doctor/Clinician Reviews Chart] --- [Individualized Decision]

Algorithm Review

[Patient claim] --- [AI/algorithm Data Match] --- [Bulk rejection (1.2 Seconds)] --- [Rubber-Stamp Physician]

The Final Logic Behind the Friction

Why would an insurer risk regulatory backlash by relying on automated rejections? The answer lies in consumer behavior and administrative friction. According to industry data, fewer than 1% to 2% of policyholders ever appeal a denied claim. Most patients assume the rejection is final, cannot navigate complex appeal paperwork, or simply pay out of pocket to avoid further stress.

100 Claims Are Denied by AI

- 98% Never Appealed
- 2% Appealed
- Insurer saves money and keeps profit
- Overturned 80-90% of the time

Medical Continuity

- Out-of-Pocket Burden
- Families shoulder thousands of dollars in surprise medical bills for covered care.



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Provider Burnout

- Doctors spend up to 13 hours a week appealing automated rejection.

The Legal and Regulatory Pushback

- The rise of automated rejections has sparked pushbacks across multiple fronts.

Class-action Lawsuits

- Plaintiffs in federal courts have alleged that using AI to issue bulk denials violates state laws requiring individual medical-necessity reviews by licensed health-care professionals.

Federal Oversight

- The Centers for Medicare & Medicaid Services have issued rules clarifying that Medicare Advantage insurers cannot rely strictly on algorithms or internal coverage criteria to deny care, demanding that decisions reflect traditional Medicare coverage standards and individualized clinical assessments.

State Legislation

- Lawmakers in states like California, Washington, and Pennsylvania have introduced or passed bills prohibiting insurers from using automated algorithm-only tools for coverage denials without mandatory, meaningful human medical review.

An algorithm trained on population averages cannot fully evaluate the human nuances, complex comorbidities, or recovery trajectory of a real person sitting in a hospital bed. **MM**



When Suspicion Is Enough: Missouri Physicians' Mandatory Reporting Obligations for Abuse, Neglect, and Related Harm

by Kathryn C. Horvatits, JD & Lisa M. Luetkemeyer, JD

Missouri law designates many professionals, who interact with children, older adults, or adults with disabilities, as mandated reporters. Physicians play a particularly important role because clinical encounters allow them to examine the body and observe signs of possible maltreatment, such as patterned bruising, unexplained fractures, or pressure injuries inconsistent with reported care, that may not surface elsewhere. This clinical proximity can make physicians the first to suspect abuse or neglect.

A physician must report to the appropriate agency when there is "reasonable cause to suspect" abuse or neglect. Although physicians may worry about the provider-patient relationship or whether their suspicion is sufficient, Missouri law makes clear that suspicion —not proof—is the trigger.[1,2,3] Good-faith reports are protected from civil and criminal liability, and reported information remains subject to confidentiality protections.





Lisa Luetkemeyer, JD, partner, Kathryn C. Horvatits, JD, associate with Husch Blackwell co-wrote this article. Husch Blackwell represents a full spectrum of healthcare providers and other businesses in developing compliance strategies, preliminary enforcement measures, employment concerns, and litigation matters. The information contained in this article should not be construed as legal advice or a legal opinion on any specific facts or circumstances. The contents are intended for general information purposes only, and readers are encouraged to consult their attorney concerning specific situations and specific legal questions.

This article offers practical guidance on Missouri's four primary mandatory reporting categories: child abuse and neglect; abuse, neglect, and exploitation of eligible adults; abuse and neglect of long-term care facility residents; and abuse and neglect of vulnerable persons in Department of Mental Health (DMH) programs. It also discusses Missouri's lack of a general mandatory reporting duty for competent adult intimate partner violence, the relationship between HIPAA and state reporting laws, and additional professional reporting obligations that may apply.

The Core Legal Standard: Reasonable Cause to Suspect

Missouri's four abuse-reporting categories share a single trigger: "reasonable cause to suspect."[4,5,6] That standard is intentionally lower than a legal finding of abuse. It does not require the physician to identify a perpetrator or conclude that abuse definitely occurred before acting. Missouri's reporting structure deliberately separates the physician's reporting role from the agency's investigatory role. Therefore, physicians should not delay a required report while attempting to conduct an inquiry that the law assigns to the state agency.[7,8,9]

The question is whether the available facts make abuse or neglect a reasonable possibility. If a physician is questioning whether the facts justify reporting, the legal threshold has likely already been met.[6,7,9] Waiting for certainty may delay protecting the victim and create legal exposure for the physician. See Table 1.

1. Child Abuse and Neglect: Who Must Report and When

Physicians, residents, interns, and "any other health practitioners" are mandatory reporters.[4] The duty arises when the physician has reasonable cause to suspect

that a child has been or may be subjected to abuse or neglect, or observes a child being subjected to conditions that would reasonably result in abuse or neglect.[4]

How Does the Statute Define Abuse and Neglect?

"Abuse" means physical injury, sexual abuse, or emotional abuse inflicted on a child other than by accidental means; reasonable discipline, including spanking, is excluded.[10] "Neglect" is the failure to provide proper or necessary support, education, nutrition, or medical or surgical care necessary for the child's well-being.[10] A child's engagement in age-appropriate independent activities without adult supervision (unless the lack of supervision is so grossly negligent as to endanger health or safety) is not considered neglect.[10] Both definitions expressly include victims of sex trafficking and severe forms of trafficking.[10] Emotional abuse is defined as observable or substantial changes in a child's behavior, emotional response, or cognition, which may include anxiety, depression, withdrawal, or aggressive behavior.[10]

What Is the Reporting Procedure?

Report immediately to the 24/7 Child Abuse/Neglect Hotline (1-800-392-3738 or 1-844-CAN-TELL) maintained by the Children's Division, or through the mandated-reporter online portal for appropriate non-emergency reports.[7] Missouri expressly prohibits internal investigation before reporting.[4] Supervisors and administrators may not impede or inhibit reporting and employers must relieve mandatory reporters of their duties long enough to make the report. No adverse employment action may be taken against a physician for reporting.[4] Child abuse reports and records are confidential and reporter identities are protected and may not be disclosed except as specifically authorized by statute.[11]

When two or more members of a medical team have knowledge of suspected abuse, one may make a joint report.[4] However, if another team member subsequently learns that the designated reporter did not file the report, they must immediately report independently.[4]

The report must include: the child's and parent/caregiver's identifiers; child demographics (name, sex, race, age); the nature and extent of injuries or circumstances giving rise to suspicion; any prior injuries; the suspected responsible person if known; family composition; and the reporter's contact information.[12] Where sexual abuse or molestation is suspected, physical evidence must be turned over to the Children's Division within 24 hours.[12]

Clinical Documentation

Thorough documentation supports the investigation and protects the physician. Findings should be documented in neutral language: exact injury location, measurements, color and stage of bruises, distribution patterns, imaging results, and growth parameters, avoiding substituting conclusions for observations.[7] Caregiver explanations should be recorded verbatim, and any child statements preserved in quotation marks, noting who was present and whether the interview was private. A well-constructed note separates what the physician observed, what the physician was told, and what the physician did (including the date, time, method, and any confirmation number provided when the report was made).[7]

2. Eligible Adult and Elder Abuse

Who Is an "Eligible Adult"?

Missouri's adult abuse statutes protect "eligible adults:" persons age 60 or older, and adults ages 18 to 59 with disabilities, who are unable to protect their own interests or meet essential human needs.[13] Eligibility turns on functional ability, not age alone. A younger adult with a significant disability may qualify, while an older adult who can protect personal interests and meet essential needs may not. Physicians should assess and document the functional basis for

protected status along with the relevant clinical findings.

Abuse, Neglect ,and Bullying Under the Statute

Missouri defines "abuse" as physical, sexual, or emotional injury or harm, including financial exploitation and bullying.[13] "Bullying" includes intimidation or harassment that would cause a reasonable person to fear for physical safety or property, including cyberbullying or other electronic communications. "Neglect" means failing to provide services to an eligible adult when the failure creates imminent danger to health, safety, or welfare, or a substantial probability of death or serious physical harm.[13]

Reporting Procedure

When a physician has reasonable cause to suspect that an eligible adult has been subjected to abuse or neglect, or observes that person in conditions that would reasonably result in abuse or neglect, he or she is obligated to report the suspected abuse or neglect immediately to DHSS.[5] Reports may be made to the DHSS Adult Abuse and Neglect Hotline or online for non-emergency situations.[14,15] The report should include: the eligible adult's name, age, and address; the name and address of the responsible person if known; the nature and extent of the condition; and any other relevant information.[16]

Adult abuse reports are often strengthened by functional and clinical detail. Physicians can materially affect DHSS triage by describing the patient's ability to obtain food, medication, wound care, transportation, and financial access; documenting cognitive impairment, delirium, dependence on the caregiver, or inability to perform essential activities; and linking objective findings, such as dehydration, pressure ulcers, uncontrolled chronic disease, or malnutrition, to risk to the patient's safety.[14,15] Documentation should clearly distinguish what was observed clinically from what the patient or caregiver reported, noting any inconsistencies between the two. Adult abuse reports are confidential and not public records, and reporter identities are protected.[17]

Clinical Nuances: Capacity, Self-Neglect, and Financial Exploitation

Many eligible-adult cases turn on capacity and dependence rather than a single discrete injury. When a patient has fluctuating capacity or is dependent on a caregiver, documentation of decision-making ability, orientation, and functional limitations helps DHSS frame an intervention that respects the patient's autonomy while reducing risk.[18]

Similarly, self-neglect may present as refusal of care, hoarding, unsafe living conditions, or medication nonadherence; in these instances, DHSS focuses on whether there is a likelihood of serious physical harm and a need for protective services.[13,18] Financial exploitation may surface through reports from the patient, family or caregivers regarding unpaid utilities, sudden inability to purchase medications, new "friends" controlling access, or coerced changes in benefits.[13] Reporting these indicators, even when based on partial information, allows DHSS to coordinate with appropriate partners and prevent rapid decompensation.[9,13]

3. Long-Term Care Facility Residents

Missouri also imposes a reporting obligation for suspected abuse or neglect of nursing home, residential care facility, and assisted-living facility residents.[19] Some potential indicators of abuse or neglect include inconsistent documentation, unexplained injuries, or signs of systemic neglect such as dehydration, pressure ulcers, or malnutrition. When a physician has reasonable cause to believe that a resident has been abused or neglected, an immediate report must be made to DHSS.[19] Suspected sexual assault of a resident requires an additional report to local law enforcement.[19] DHSS must investigate such reports within 24 hours.

Table 1. Missouri Mandatory Reporting Quick-Reference

Patient Category	Reporting Agency	Hotline / Contact	Primary Statute	Key Point
Children (under age 18)	Missouri Children's Division (DSS)	1-800-392-3738 or 1-844-CAN-TELL (24/7); online (non-emergency): dss.mo.gov/cd/can.htm	§§ 210.115; 210.120 RSMo	No internal investigation before reporting; employer must provide immediate access to communications technology. In medical institutions, photographs of trauma, x-rays if indicated, and immediate notification of the physician in charge is required — no consent required.
Eligible adults (persons 60+; disabled adults ages 18–59 functionally unable to protect own interests)	DHSS Adult Protective Services	1-800-392-0210 (7 a.m.–midnight, 365 days/year); online (non-emergency): moapss.health.mo.gov	§§ 192.2400–192.2435 RSMo	Eligibility is functional, not age-based alone; include capacity, functional status, and risk detail in the report.
Residents of nursing homes, residential care facilities, or assisted-living facilities	DHSS; local law enforcement for suspected sexual assault of resident(s)	1-800-392-0210; 911 for sexual assault or imminent danger	§ 198.070 RSMo	Separate facility-specific statute; DHSS must investigate within 24 hours; report to law enforcement for sexual assault.
Patients, residents, or clients in DMH-operated, licensed, funded, or certified programs	Department of Mental Health	DMH reporting line; see dmh.mo.gov for current contact information	§§ 630.162–630.165 RSMo	Steepest penalty structure; first violation includes up to $1,000 fine; subsequent violation is a Class E felony.
Patient with a gunshot wounds	Local law enforcement	911 or local law enforcement non-emergency line	§ 578.350 RSMo	Mandatory reporting obligation separate from abuse/neglect; assess whether other reporting obligations also apply.

4. Vulnerable Persons in Mental Health Programs

Missouri's fourth mandatory reporting framework applies to physicians practicing in mental health facilities, developmental disability programs, and other settings operated, funded, licensed, or certified by the Department of Mental Health ("DMH").[6] A physician in a covered setting must immediately report relevant information in writing or orally to DMH when there is reasonable cause to suspect that a patient, resident, or client has been abused or neglected, or is in conditions likely to result in abuse or neglect.[6,20] DMH must begin an investigation within 24 hours.[21] Physicians in DMH-covered settings should also assess whether overlapping eligible-adult or facility-resident reporting duties apply.[6]

Intimate Partner Violence: No General Missouri Mandatory Reporting Obligation for Competent Adults

Missouri does not impose a general mandatory reporting obligation on physicians for suspected intimate partner violence ("IPV") between competent adults. Where Missouri law leaves discretion, a patient-centered approach that

prioritizes safety planning and resource referral is consistent with evidence that mandatory IPV reporting can deter survivors from seeking care and may worsen outcomes.[22,23]

Physicians should carefully assess all applicable frameworks before concluding that no mandatory duty exists. If the IPV victim is 60 or older, or is a qualifying adult with a disability who cannot protect themselves, the eligible-adult obligation applies independently from the domestic-violence context.[5] If children in the household are exposed to violence in circumstances creating reasonable suspicion of abuse or neglect or if the victim is a facility resident or a DMH patient, other reporting requirements may apply. [4,6,19]

Gunshot Wounds

Missouri separately requires an immediate report to local law enforcement for gunshot wounds.[24] That reporting obligation is outside the scope of this article's central focus on abuse and neglect but is worth noting because gunshot wounds frequently arise in cases that may implicate other mandatory reporting obligations addressed in this article.

HIPAA, Confidentiality, and Privilege

HIPAA does not prohibit mandatory reports required by state law. HIPAA expressly permits covered entities to disclose protected health information to public health authorities authorized to receive reports of child abuse or neglect, and to government authorities authorized to receive reports of adult abuse, neglect, or domestic violence when disclosure is required by law.[25] Missouri's mandatory reporting statutes satisfy the "required by law" standard for HIPAA purposes, and these disclosures comply with HIPAA without requiring separate patient authorization. Concerns about HIPAA should not delay or prevent a required report; in the mandatory reporting context, HIPAA enables such disclosures rather than being a barrier.

Reports under all four Missouri categories are confidential once made, and reporter identities are protected in each statutory framework. For child-abuse reports and cooperation with the Children's Division, Missouri law overrides nearly all evidentiary privileges, including the physician-patient privilege, with limited exceptions for attorney-client and clergy communications.[26] While no comparable blanket privilege override exists in the adult-abuse or DMH statutes, each reporting obligation imposes criminal penalties for knowing non-compliance, effectively ensuring that privilege does not operate as a shield against the reporting duty.

Consequences of Non-Compliance

Failure to comply with the state's mandatory-reporting statutes carries significant legal and professional consequences. In most cases, failure to report constitutes a Class A misdemeanor, which may include fines and possible imprisonment.[19,27,28,29] Case law reinforces the seriousness of these obligations. Missouri courts[2],[3] have upheld criminal liability for failure to report abuse of a nursing home resident and emphasized that the duty to report persists even after the victim's death.

Beyond criminal exposure, physicians may also face disciplinary action from licensing boards, adverse employment consequences, and reputational harm.[7] [30] Missouri's reporting statutes generally do not create a private cause of action for failure to report, but civil liability may arise under broader negligence theories in certain circumstances.

Immunity and Protection for Good-Faith Reporting

To encourage compliance, Missouri law provides broad immunity for physicians who report suspected abuse in good faith. Immunity from civil and criminal liability is granted for making a report, participating in

an investigation, cooperating with authorities, and participating in related judicial proceedings.[31] This immunity is intentionally expansive, applies regardless of the outcome of the investigation, and is lost only in narrow circumstances, such as reporting to the incorrect agency, intentionally false reporting, or bad faith.[31,32]

Immunity is narrower under the eligible-adult and facility-resident regimes: it may be lost for negligent or reckless conduct, as well as bad faith or malicious purpose.[19 33] Physicians should base each report on good-faith clinical judgment, not expediency or external pressure. In practice, the legal risk of reporting in good faith is low and the risk of failing to report when required is far greater.

Additional Professional and Institutional Reporting Obligations

Physicians may have separate reporting obligations under medical staff bylaws, employment agreements, accreditation standards, or other professional requirements. These obligations run alongside, and do not replace state-mandated reporting duties. Failure to comply may result in employment discipline, medical staff corrective action, or credentialing consequences. Physicians should understand the reporting requirements specific to their practice setting.

Conclusion

Missouri's mandatory reporting framework requires physicians to act on suspicion, not certainty. Waiting for confirmation can leave a patient at risk and expose the physician to criminal liability. By reporting in good faith, the physician shifts investigation to the appropriate agency, receives statutory protection, and may help prevent further harm. When obligations overlap, privilege or confidentiality questions arise, or institutional reporting requirements are unclear, physicians may wish to consult legal counsel, but legal review should not delay a report required by law. In Missouri, timely reporting is both a legal duty and an act of patient advocacy.

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The Lawsuits Will Continue Until Morale Improves

by Cory L. Andrews, JD

A California court holds a pharmaceutical company can be found liable for not innovating quickly enough.

The California Supreme Court takes up a strange question Wednesday: Can a pharmaceutical company be sued for negligence not because its Food and Drug Administration-approved drug was defective or its warnings insufficient, but because the company didn't bring a better version to market sooner? The California Court of Appeal answered yes in a 2024 decision. It invented a tort out of failing to innovate fast enough. If the state high court lets this ruling stand, it won't merely distort product-liability law; it will punish medical progress.

Gilead developed tenofovir disoproxil fumarate, or TDF. The FDA approved it in 2001 as Viread and in 2004 as Truvada. These breakthrough medications converted HIV from a death sentence into a manageable chronic illness, saving millions of lives. While working on TDF, Gilead explored an alternative therapy: tenofovir alafenamide, or TAF. Early tests looked promising, but the company paused development in 2004. The choice was rational: Long-term safety data was unavailable, efficacy thresholds hadn't been cleared, and further investment in an unproven compound risked starving proven therapies of resources.

Gilead returned to TAF in 2010, engaging in years of painstaking research and costly clinical trials. Gilead launched TAF-based medicines in 2015 with comparable antiviral power and meaningfully improved kidney and bone safety for some patients. Plaintiffs here don't claim those drugs or the TDF ones were defective. They don't allege inadequate warnings about known risks. Their theory is that Gilead should have commercialized TAF earlier. They allege that the company dragged its feet to squeeze extra profit from TDF patents.

The Court of Appeal embraced that claim. It held that a manufacturer can breach a duty of reasonable care merely by pausing or delaying a "safer" alternative—even when the existing product met every regulatory and tort-law standard of its era. Traditional product liability demands a defect in the product or its labeling. This ruling discards both requirements. It converts ordinary scientific and business judgments into actionable negligence.

This is a radical break from the law. Product liability has always turned on product risks a manufacturer introduces to market, not on hypothetical improvements it might have rushed to consumers. Imposing a duty to accelerate every promising alternative would force companies to revisit every strategic pause, every resource allocation, and every clinical decision through the distorting lens of hindsight. Otherwise, juries lacking scientific or regulatory training could be asked to pronounce whether billion-dollar research-and-development choices were "reasonable" years after the fact.

The consequences of this new "tort" are predictable and perverse. Developing a new drug already costs more than $1 billion and takes more than a decade. Follow-on innovations like TAF are the lifeblood of medical progress. Yet they are among the first casualties when litigation risk spikes. Companies will respond by either rushing half-baked products to market, steering clear of high-risk diseases, or abandoning incremental advances that might later trigger should-have-done-it-sooner tort suits. Prices will rise, as the few drugs that



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still reach patients will carry a new tax of unpredictable liability.

There is a proper place to regulate drug risks: the federal scheme Congress and the FDA designed. Regulators approve drugs on the evidence available at the time. They demand rigorous proof of safety and efficacy; they don't require clairvoyance. The California Court of Appeal's approach lets state juries override those contemporaneous judgments, declaring after the fact that a company should have moved faster with data that at the time didn't justify the leap. Judges and jurors are ill-suited to referee such intricate scientific and commercial calls. The proper arena for weighing innovation incentives against safety is the federal regulatory process—not after-the-fact state tort suits.

California, a historic leader in technology and life sciences, risks becoming the jurisdiction where tomorrow's cures are litigated into nonexistence. Activists may cast a reversal of the appeals court decision as a win for drug companies at patients' expense. But that is a false dichotomy. Patients today enjoy longer, healthier lives thanks to the iterative process this lawsuit would penalize. The earliest HIV therapies were crude and toxic. Each refinement arrived because companies had room to experiment, to fail and try again—without fearing that every prudent pause would invite a payday for lawyers. Penalizing the scientific caution that careful safety requires doesn't speed or improve cures.

The California Supreme Court has a clear path forward. It can reaffirm that product liability requires a defective product or inadequate warning—not judicial oversight of R&D timelines. It can safeguard the incentives that have made American pharmaceutical innovation the envy of the world. And it can do so while preserving every traditional tool for holding companies accountable when they truly cut corners on safety or conceal known risks.

The stakes reach far beyond this case. If California blesses liability for the pace of innovation, other states will feel the pull. The result won't be safer or faster drugs. It will be fewer of both. Medical miracles depend on risk-taking, not on risk-free litigation. California's patients—and the nation's deserve no less. **MM**

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Doctors versus The Dogs

by Norman P. Knowlton, III, MD

As a physician and as a patient, it really teaches us to live every day to the fullest.

I grew up in St. Louis with a physician father who was integrally involved with Internal Medicine at Washington University and Barnes Jewish Hospital. He practiced for long hours and was dedicated to his patients. He spent a great deal of time teaching young doctors and caring for his patients, while trying to spend time with our family.

I matriculated at the University of Colorado and graduated with a Bachelor of Arts in Biology with an area of emphasis in genetics. I love the outdoors and sciences, so I decided to go into Wildlife Administration. After graduating I wished to attend the University of Colorado's postgraduate program in Wildlife Administration but, being from out of state (Missouri) all the students they selected were from Colorado. I came back to University of Missouri in Columbia to continue my degree in Wildlife Administration. While working on my master's degree, one of my professors in Cytogenetics encouraged me to apply to medical school. I did and was accepted into the Saint Louis University School of Medicine.

When I started medical school, I truly did not know what area of medicine I wanted to pursue. I thought about Orthopedic Surgery since I love sports. The length of training including residency, research, and labs told me I did not want to spend an additional five to seven years in that process. I love being with patients and living alongside them. So, Internal Medicine filled the bill. Subspecialties were too specialized, so I went into general Internal Medicine. Being obsessive-compulsive personality drove me further toward Internal Medicine. I trained under the very demanding professor Charles Mengel, MD at MU School of Medicine

In 1978, I started my practice in a small group of three Internists in Springfield, Missouri. Because of the unmet need for primary care, our group grew rapidly. Three resident physicians that served with me at MU came on board and our group grew rapidly to 15 members.

While serving my patients and colleagues I became involved with many committees and served as chairman, not only at the hospital, but also as President of Springfield Clinic of Internal Medicine. I got my first glance at administration. I was coerced by my peers to run for office at the hospital—St. Johns Regional Health Center, and advanced to the Chairman of the Department of Medicine and eventually the Chief of Medicine. I was a member of Greene County Medical Society, Missouri State Medical Association, and the American Medical Association from the initial day of my practice. During the same time, I also was encouraged to run for office in MSMA and ran through the chairs over the next 15 years to become President of MSMA in 2001.



Norman P. Knowlton, III, MD, is an Internal Medicine physician in Springfield, Missouri. He served as MSMA President in 2001-2002.



Dr. Knowlton and his wife, Mary Nan Knowlton.



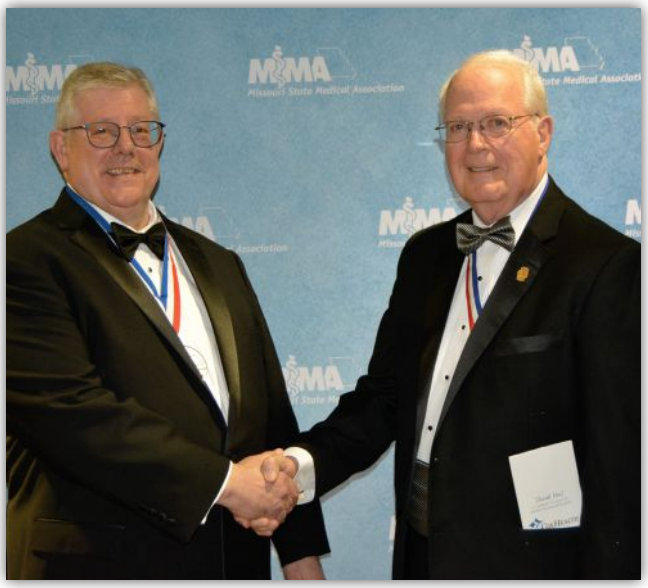
Twenty-five years past Dr. Knowlton's Presidential year, he is still a frequent participant during MSMA's Annual Convention.

Not skilled at saying "no", I accepted positions on many committees including serving MSMA as the liaison between MSMA and MAOPS (Missouri Association of Osteopathic Physicians and Surgeons). This started the communication and integration of MSMA and MAOPS today. I was assigned by the MSMA Council to serve as its liaison to the State Board of Registration for the Healing Arts which licenses and regulates physicians. I was appointed as liaison to the Missouri Hospital Association to help with addressing contacts between hospitals and physicians, and to the Missouri Association of Trial Attorneys to help negotiate legislation concerning liabilities issues. I was appointed by MSMA to serve as a director and medical consultant to Blue Cross/Blue Sheild. This gave me good insight into the way insurance companies view their enrollees. While working with the MSMA Executive Vice Presidents Royal Cooper and Cork Swarens, we helped negotiate the buyout of MOMEDICO (Missouri Medical Insurance Company) to Mutual Assurance of Alabama which generated enough funds to make MSMA dues down to one of the lowest costs in the country for perpetuity.

We helped streamline the duration of the MSMA Annual Convention down to just one weekend. This helped keep the MSMA costs down. This again gave me insight into the real world of malpractice and the insurance world. All of these provided opportunities to help physicians and patients to get high quality, affordable medical care.

Medical practices had been driven from fee for service care to managed care—which some would call "managed money." Doctors provide medical care and administration manage their practices. Medical systems demanded increased volume of patient encounters to provide increased revenue.

Patient's care changed. Computers, laptops, and bean counters took more time to deliver the best care. In order to provide older patients with multiple problems, with multiple medicines, with interested families, required more time. This was definitely very frustrating to all physicians. I left St. Johns Regional Health System and practiced the



David Pohl, 2024-2025 MSMA Present, presents Dr. Knowlton with his 50-Year Physician pin.

next 13 years in the Diagnostic Clinic at Cox South Health Center in Springfield ,Missouri with less administrative involvements and more direct patient care.

Loving the outdoors since the practice of Internal Medicine usually doesn't allow the time or opportunity to spend time with family. I made a point of spending quality time with my two boys hunting, fishing, and trying to stay in shape by jogging and biking. Having very active sons lead me on the path to become trained with the American College of Sports Medicine to be a team physician. I served as team physician for Springfield Catholic High School Football program for 14 years at all their football and other sporting events. For serving the Catholic High School in the football program I was inducted into the Missouri Sports Hall of Fame with the Springfield Catholic Team. Having more time with less administrative duties, I served as Medical Director for the Ozark Honor Flight. I took and cared for more than 1,200 WWII veterans to visit their respective Memorials in Washington D.C.. This helped encourage my patriotic and civic endeavors. I am a member in the Sons of the American Revolution and presently serve not only my local Ozark Mountain Chapter but also serve as the Missouri Society of the Sons of the American Revolution as its State Surgeon.

After going through a divorce and rearing my two sons in their multiple involvements, my second wife of 23 years, Mary Nan Knowlton and I got involved with training dogs. We have trained our Golden Retriever dogs in multiple venues including AKC titles in Obedience, Rally, Fetch, Fast C.A.T., Scent Work and especially in Pet Therapy.

We have provided Pet Therapy to multiple people in many facilities. We have been certified to provide care at Springfield Cox South Health Center and have visited patients in Oncology. Neurology, Outpatient Physical Therapy, Rehabilitation, and its Infusion Center. These therapy dogs have been shown to greatly enhance patient care.

We also visit other locations including Lakeland Behavioral Center, Missouri State University. Ozark Technical College,and Springfield schools to provide final exam stress relief. We do special visits to nursing homes and other events to put smiles on people's faces.

My wife, our dogs, and I have been honored by many organizations. We received a nomination for the Gift of Time Award from the City of Springfield and the Springfield Chamber of Commerce. We received the Hospital Hero's award from the Missouri Hospital Association and a special award from President George H.W. Bush and Barbara Bush of the 10,000 Points of Light Award for our Pet Therapy and volunteering.

Pet Therapy does provide a care that a human cannot provide. It is fun, it is rewarding in a different way, and it provides a healing experience which expedites the patient's recovery.

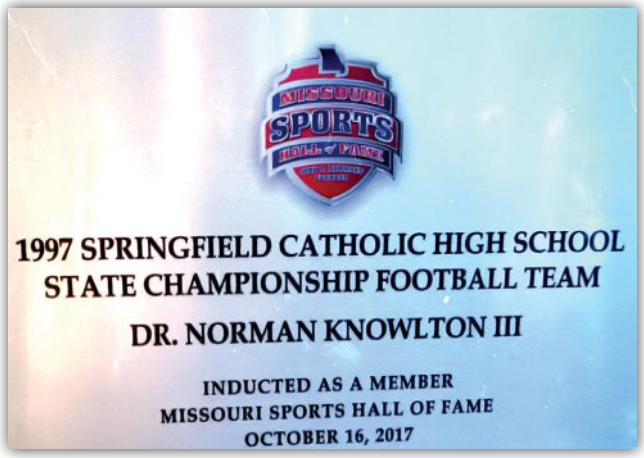
I retired from active practice in 2013, and I am still Board Certified with meeting of certification in Internal Medicine. I've truly enjoyed life after active practice in medicine and will and have loved my relationships with caring for my patients. Now hospitalists have taken hospital care from doctors that have cared for them for years. I knew my patients well and

hospitalists did not. Communication between hospitalists and their primary care physicians became quite limited for continuity of care. This is another spike that led me to retire. My patients to this day frequently contact me for directions, advice and referrals into this melange of medical systems that does not provide access well. In medicine, I always tried to prioritize my patient care first, doctors second, hospitals third, and insurance companies last. It seems to be going in a different direction.

Unfortunately, in August of 2025 I was diagnosed with stage 4 aggressive Non-Hodgkins Diffuse B cell lymphoma. I was treated with R-EPOCH chemotherapy this past year. I am now in remission. As you can see life doesn't end when you leave practice…it only begins. As a physician and as a patient it really teaches us to live every day to the fullest.



Dr. Knowlton and his wife have provided Pet Therapy to multiple people in many facilities, including hospitals, behavioral health centers, schools, and nursing homes.



For serving the Springfield Catholic High School in the football program Dr. Knowlton was inducted into the Missouri Sports Hall of Fame with the Springfield Catholic Team.



Dr. Knowlton (far left) with six Washington University School of Medicine physicians received the Knowlton Incentive for Excellence award during a 2022 award ceremony hosted by The Foundation for Barnes-Jewish Hospital. The awards recognize and support medical residents who exemplify a compassionate spirit combined with outstanding knowledge and skill.

The fund was established in 1984 by St. Louis real estate and business leader Charles J. Cella to honor his physician, Norman Knowlton Jr., MD, (Dr. Knowlton's father) for his compassionate caregiving. Dr. Knowlton was a professor emeritus of clinical medicine in internal medicine at Washington University and Barnes-Jewish Hospital.

The Knowlton fund is stewarded by a committee chaired by Dr. Norman Knowlton, III. John Cella, Charles J. Cella's son, also serves. In the past 35 years, more than 200 awards have been given to fellows who have completed internal medicine residency programs, embody the "Knowlton spirit" of care, and are likely to practice in the St. Louis area.

MM

Health Care

Mizzou School of Medicine Expands in Springfield to Grow Missouri's Physician Workforce

by David Haustein, MD, Andy Oldenburg & Travis Zimpfer

"Rural health care providers are vital to serving Missouri communities that are often under-resourced and overlooked. We are grateful for the partnerships with CoxHealth and Mercy Springfield communities and their support in our University's steadfast dedication to work for all Missourians."

With a growing population and a retiring physician workforce, Missouri is projected to face a physician shortage of more than 3,000 physicians in the next 10 years. The University of Missouri is strengthening the state's future health care workforce with a new Springfield facility that will help train more physicians to serve communities across southwest Missouri and beyond.

Since 2016, the University of Missouri School of Medicine, in partnership with CoxHealth and Mercy Springfield Communities, has trained third- and fourth-year students in Springfield—Missouri's third largest city after St. Louis and Kansas City.

As a two-year campus, Mizzou students spent their first two years in Columbia before moving to Springfield for two years of clinical training. Over 80% of these students are from Missouri, and many come from southwest Missouri. Over the last 10 years, the Springfield campus has already produced 170 more physicians who have matched into competitive residencies across the state and nation.



Ribbon-cutting ceremony at MU's School of Medicine Springfield Campus

Starting in 2027, Mizzou will expand the Springfield program to host all four years of the medical school curriculum for 32 students per class. This expansion will broaden the opportunities for Missouri students to become physicians, especially those from southwest Missouri. By 2030, the site is expected to have four classes of 32 students for a total enrollment of 128. Together with the Columbia campus, Mizzou's School of Medicine will enroll a total of 672 medical students.



David Haustein, MD, MBA, (pictured), is Associate Dean, University Missouri School of Medicine Springfield Campus, and Professor, Physical Medicine and Rehabilitation, Springfield, Missouri, USA. Andy Oldenburg University of Missouri School of Medicine Communications Manager and Travis Zimpfer is University of Missouri Deputy Spokesperson, Columbia, Missouri, USA.

"Mizzou is proud to grow our presence in Springfield and to train even more world-class physicians who will impact the health and future of our rural communities," University of Missouri President Mun Choi said. "As Missouri's flagship, land-grant university, we are committed to preparing leaders who will build on the Springfield program's legacy of excellence to make a difference across the state."



MU's School of Medicine Springfield Campus building.



Simulation Lab at MU's School of Medicine Springfield Campus.

On June 24, 2026, University of Missouri leaders joined state and community officials to celebrate a ribbon cutting of the new medical school site in Springfield at 3737 East Battlefield Road. This facility doubles the size of the prior facility and will offer 50,000 square feet of space for the medical school program and will house the regional medical campus, which will include classrooms, conference rooms, and a simulation center. Renovations started in the fall of 2026 and are expected to be completed in June 2027, in time to welcome the inaugural class of first-year medical students in July 2027.

Curriculum at the Springfield Campus will be comparable to what students receive at Mizzou, with faculty resources and an expanded simulation lab shared across both sites. University leaders also have established partnerships with Springfield-area colleges and universities to provide pathways to Mizzou's School of Medicine in Springfield with the goal of encouraging local students to pursue medical education close to home and to remain in the region after degree completion.

"Rural health care providers are vital to serving Missouri communities that are often under-resourced and overlooked," Todd Graves, chair of the University of Missouri Board of Curators, said. "We are grateful for the partnerships with CoxHealth and Mercy Springfield communities and their support in our University's steadfast dedication to work for all Missourians."

The expansion's potential impact on the region's workforce is already evident to students training in Springfield. Fourth-year Mizzou medical student Nicole Walker believes the new facility will encourage more graduates to remain in southwest Missouri after completing medical school and will create research and teaching opportunities in the area. Walker chose Mizzou's Springfield Campus for her training because of its supportive environment and opportunities for hands-on learning. Since arriving, she has assisted in surgeries, helped deliver babies, participated in patient rounds and developed mentoring relationships with faculty physicians. "With every decision that I make and every obstacle that I face, I know there is an entire community of people who will do everything they can to help me succeed," she said. "I am very excited to see what the future holds with the expansion of the Springfield Campus."

"Medicine is ultimately about people," Ross Zafonte, Interim Hugh E. and Sarah D. Stephenson Dean of the University of Missouri School of Medicine, said. "The farther we extend our reach into communities across Missouri and beyond, the closer we bring care to those who need it most. This growth is about far more than expanding educational opportunities. It is about cultivating a new generation of physicians who understand the unique health needs of the communities they serve because they trained there, lived there, built relationships there, and ultimately chose to stay there. In doing so, we strengthen access to care, improve health outcomes, and fulfill our mission to serve all Missourians." **MM**

MU Health Care

Contemporary Issues in Missouri Trauma Care

by Jeffrey Coughenour, MD

The future of trauma care is bright. With persistence, we can achieve great things while, as Dr. Mitchell often said: "Keeping the patient at the center of everything we do."

American trauma care began to mature in the late 1960s and early 1970s, largely from the influence of military-trained surgeons and their experience in casualty care. The American College of Surgeons (ACS) published the first *Optimal Hospital Resources for the Injured Patient* in 1976,[1] which served as a resource guide for trauma center designation and broader trauma system development.

About ten years later, in 1987, Mizzou's own Frank Mitchell, MD chaired the College's initial Ad Hoc Committee on Verification/Consultation. The work to validate resources and improve care would later become known as the Verification, Review, and Consultation (VRC) Program. The trauma center at the University of Missouri was named after Dr. Mitchell in 2009, becoming one of only four or five centers in the US to honor the legacy of a trauma care pioneer in that way.

This short history lesson establishes context. I deeply value our performance at each re-verification survey, when we can demonstrate the patient-centered care the multidisciplinary team provides. After all, our center's namesake helped establish the process. As we prepare for the next Committee on Trauma VRC visit in 2027, I will describe the injured population in central Missouri and the clinical quality initiatives we are focused on. Additionally, I'll share my perspective on some very important discussions occurring within the broader trauma care community across Missouri. With open-minded and engaged stakeholders, I believe we have the potential to shape the largest improvements in our statewide system in decades.

Demographics and Quality Initiatives

The Frank L. Mitchell, Jr MD Trauma Center at MU Health Care serves a population of about 600,000 over a 26-county primary catchment area. All but Boone and Cole County carry a rural designation, like 99 of Missouri's 114 counties.[2,3] Patient volumes have oscillated over the last five years. Patient volumes were highest in 2020, declined through 2022, then started to increase at a rate of about 9-10% per year.

Approximately 2,600 patients were evaluated following a full or partial trauma team activation representing about 5% of all emergency department visits at University Hospital. The trauma season is also



Jeffrey Coughenour, MD, FACS, is Professor of Surgery and Emergency Medicine, Trauma Medical Director, Division of Acute Care Surgery, Hugh E. Stephenson, Jr MD Department of Surgery, University of Missouri School of Medicine, Columbia, Missouri, USA.

persisting later than usual. In 2025, October was our busiest month while the last quarter of the year added nearly 600 patients to the trauma registry, or about 28% of the year's volume. The blunt to penetrating mechanism of injury ratio is 94:6; the predominate presentation is the geriatric ground-level fall with 36% of our patients aged 65 or over. [4]

Despite the perceptions that may accompany the elderly population, ground-level fall is not inconsequential. One-quarter of our patients are severely injured with an injury severity score (ISS) at or above 15 (ISS range 1-75, with a score of 15 or greater labeled severe). A significant number require ICU-level care and inpatient rehabilitation or skilled nursing care at discharge. Objective measures such as the trauma specific frailty index have become vital screening tools for inpatient resource utilization, disposition planning, and developing post-discharge plans involving family and primary care practitioners.[5]

During my 14-year tenure as trauma medical director, the age over 65 cohort has risen by about 1.1% per year. And it isn't just a rural issue. An informal conversation with two colleagues in urban centers noted a decrease in their penetrating mechanism of injury percentage, largely due to the steadily increasing injured elderly outpacing any changes in assaults, gun violence, etc.

There is another key metric that deserves emphasis: 75%. Significant effort is dedicated to the performance improvement and patient safety (PIPS) process during daily trauma center operations. The methods and documentation are thoroughly assessed during each re-verification visit. While every injured patient receiving care in our system is screened, the majority undergo some degree of additional review. At Mizzou, that's about 75%. Complementing the institution's review process, ACS verified centers also participate in the Trauma Quality Improvement Program (TQIP)® which generates a risk-stratified benchmark report twice each year.

Our current focus from national data is ventilator-associated pneumonia (VAP). After previously improving, the number of VAP events are climbing again with the highest risk among patients with severe traumatic brain injury. Daily sedation pauses/assessment for readiness to extubate, aggressive mobilization efforts, and early tracheostomy (within seven days) for patients likely to require prolonged mechanical ventilation are top of mind. The PIPS team will query faculty anytime there is a question about radiographic findings to ensure the patient satisfies all elements of the National Trauma Data Standard (NTDS). We have also augmented our clinical care by administering a single dose of ceftriaxone within 12 hours of intubation, purported to decrease the incidence of early VAP in a 2024 publication from France.[6]

Next is the increased use of high-fidelity simulation and reinstituting video review of trauma team performance. While we have a robust policy defining the roles and responsibilities of each team member, performance is occasionally suboptimal. Overcrowding, lack of attention to detail, and overemphasis on procedural skill opportunities can hamper the efficient initial evaluation and management of the severely injured. Combating complacency, we've planned a series of no-notification high-fidelity simulation events. A pregnant simulator is wheeled into the resuscitation suite mid-morning, testing the notification process, response, and coordination of surgical priorities among several teams.

In addition, we're pursuing purchasing an audiovisual monitoring platform that incorporates patient monitoring data, offering a unique review of team performance and efficiency. The military-derived principle says "train like you fight, fight like you train," emphasizing performance under stress mirrors training, not intent. In a smaller non-trauma hospital, the same idea applies. Find a mannequin and attach any reasonable clinical scenario. Do the appropriate people respond to your emergency department in a timely manner? Do they possess the clinical decision-making and procedural skill to provide minimally acceptable care before executing a timely transfer to a higher level of care?[7] I'll never forget a group of nurses from a southwest Missouri critical access hospital's emergency room that told me their ED physicians cannot place chest tubes… 'we have to call the helicopter.' Hope the weather's clear.

Two less common issues worthy of attention are pre-hospital tourniquet application and treatment of out-of-hospital traumatic arrest. There is no debate that early extremity tourniquet application saves lives, but we continue to see them applied for questionable indications such as open fractures with venous bleeding or penetrating injuries well away from major arteries.[8] We may be victims of our own success (and the Stop the Bleed Campaign®). A 2021 five-year review at two Boston centers noted 51% of pre-arrival tourniquets were clinically indicated and 27% were inappropriately placed.[9] Fortunately, most transport times across our

region are within 90 minutes of injury and risk of morbidity is low (3.4% in reference). I don't get on our first responders too heavily about it, but I challenge the team—'the surgeon shouldn't be the only one that knows major vascular anatomy and what arterial bleeding looks like.' Direct pressure, pressure dressings, and wound packing are sufficient in most cases.

Finally, the treatment of traumatic cardiac arrest should begin to change. Several professional organizations collaborated to publish a long-awaited standardized, joint position statement in June 2025.[10] Briefly summarizing, out-of-hospital traumatic cardiac arrest is a distinct clinical entity with different causes, treatment, and survival statistics compared to medical arrest. Resuscitation based on external CPR and numerous doses of epinephrine isn't helpful. Initial efforts should be laser-focused on identification of potentially reversible causes and performance of life-saving interventions, which are often basic (hint: endotracheal intubation isn't on the list). The paper goes on to discuss considerations for transport and discontinuation of care, which is more involved than I have time for here. Another very useful take-home point is the presence or absence of cardiac motion is superior to electrical activity when predicting survival.[11] If your regional EMS services aren't equipped with point-of-care ultrasound, why not?

Improving the System

In the early 2000s, grant funding from the Missouri Foundation for Health energized the Department of Health and Senior Services (DHSS) to re-examine the state's emergency care system. Championed by Bill Jermyn, DO, Governor Matt Blunt signed House Bill 1790 into law on July 10, 2008; the nation's first effort to consolidate trauma, stroke, and STEMI care into a unified public health effort. Surgeons expressed concern that the trauma system would stagnate while attention was diverted to developing stroke and STEMI center designation. DHSS leadership agreed to invite the American College of Surgeons to complete a comprehensive trauma system consultation. The process and its final report, led by Michael Rotondo, MD, outlined 85 recommendations in numerous areas including health policy development, finance, clinical care, and data management/quality assurance. Fourteen recommendations were deemed "most important for the trauma system's short and long-term success."[12 (pg. 7)]

In my opinion, only three of them were successfully completed. Thankfully, I believe the right people are finally in the right place at the right time.

Arguably the most significant change being discussed is transitioning to national verification for all Level I and II trauma centers. Common complaints about the state designation process were inconsistent knowledge and application of outdated regulations and a hospital's ability to mire deficiencies or an unsuccessful review in legal challenges while remaining designated.

In contrast, the current College VRC standards are THE contemporary standard of care for trauma. Reviewers undergo robust training, junior reviewers are paired with senior experienced members, and there is a clear process when a program is deficient in one or more areas. Cost is the most frequently cited barrier. A state review (every three years) is about $6,000 while our recurring annual cost for ACS verification and TQIP® participation is approximately $30,000. For three of our Level I and all seven of the Level II centers, a significant initial cost would likely be required (additional human and material resources necessary to meet standards, the consultation and verification visit). In a multi-million-dollar hospital or health system, the cost is almost assuredly affordable. Increased patient volumes, improved downstream revenue, benefits to payer contract negotiations, and most importantly—improved mortality are all described in the literature.[13-15] DHSS leadership recognizes a cost savings to the state by eliminating duplicated services and appear to be supportive.

Level III centers would continue to be designated by DHSS. To that end, significant work continues to update our state's trauma system regulations to align with the current version of the Resources for Optimal Care of the Injured Patient (2022 Standards).[16] Establishing criteria for Level IV centers is also being discussed and should be strongly encouraged. There are several areas that lack adequate trauma center coverage. The map (Figure 1) from DHSS's Time Critical Diagnosis portal demonstrates gaps within the southeast, the I-49 corridor, and much of north central/northwest Missouri. There are emergency departments in many of these underserved areas; we should assist several of them to become Level IV centers. Improving trauma system access is an achievable goal.

For example, Kentucky now has 15 Level IV centers, most at critical access or small rural hospitals. Several more are currently under development. Cost estimates for a new Level IV center are estimated as high as $80,000; state funding, add-on payments such as the Kentucky Hospital Rate Improvement Program, and private sector donations would likely be necessary to offset costs for hospitals potentially currently in some degree of financial stress.[17-18] Alternatively, all hospitals could be mandated to achieve some level of designation, such as in Iowa. At a bare minimum, each of Missouri's 161 hospitals should submit data to the state trauma registry as a condition of licensure (currently only required of the 29 designated trauma centers). This would allow for a more accurate measure of system performance to identify opportunities for improvement.

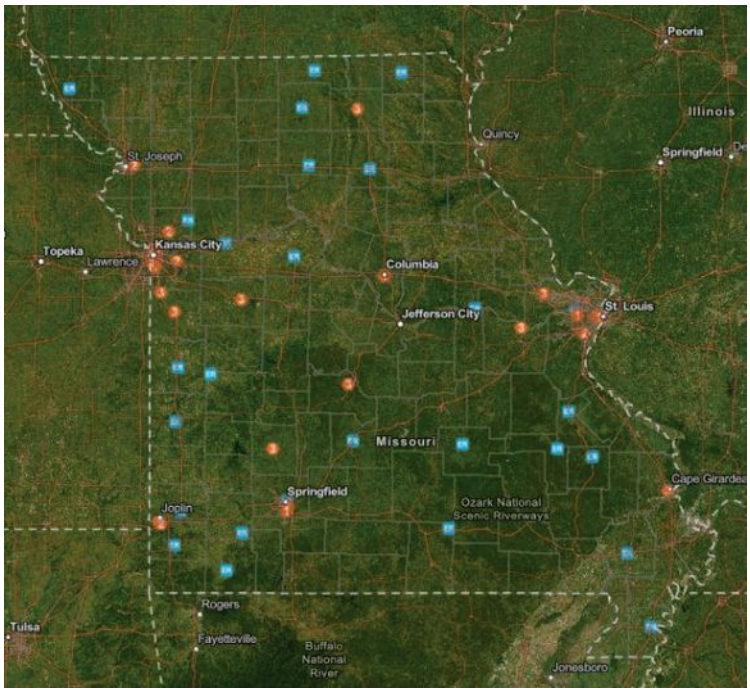


Figure 1: Screenshot of interactive map; Missouri Department of Health and Senior Services, Time Critical Diagnosis Program. Orange circles represent trauma centers. Blue squares represent non-trauma center emergency departments.

Source: https://experience.arcgis.com/experience/e35fe21316474f349ac056b15f90bbef/page/Map-View/#data_s=id%3AdataSource_2-1fd65497a76d4bbcb2173ccffc50875b%3A144

Other work is being done to update the current "15-mile rule." First enacted in 1989, Missouri regulation 19 CSR 30-40.430(1)(M) states in part "There shall be no level III trauma centers designated within fifteen (15) miles of any Missouri Level I or II trauma center." The concept was to prevent the proliferation of lower-level centers within proximity to larger tertiary care centers, preventing dilution of trauma patient volume (and thus experience and efficiency of care) at any one center and to prevent secondary transfers (the idea of an injured patient going to the lower-level center first, then determining they require resources only available at the larger center).

The parent corporation of St. Joseph's Medical Center in south Kansas City challenged the rule in Cole County Circuit Court after their application for a Level III trauma center was denied. The courts upheld the validity of the rule in 2021 and again in the Missouri Court of Appeals – Western District in 2022.

Despite this, several trauma center leaders believe we could do better. The ACS has proposed a needs-based assessment tool as a data-driven method to determine the optimal number of trauma centers within a particular region. The tool uses total population, transport times, the number of severely injured patients, and existing volume at existing centers (with predicted volumes based on new centers under consideration).

First developed in 2015, there has been limited application of the process, but it serves as an excellent framework for this effort at a regional level.[19]

This past legislative session, there were two bills proposed in the Missouri House of Representatives to abolish the regulation without proposing an alternative. Both were sponsored by representatives from south Kansas City (HB 1805, Sharp-D, Jackson and HB 1810, Mansur-D, Jackson); identical bills in the 2025 session saw no meaningful action.

I would like to mention one other legislative effort. As many of you know, many health care practitioners in Missouri enjoy robust peer review protection in RSMo 537.035. Ten "health care professionals" were defined when the statue became law in 1973. Because they didn't exist at the time, EMTs and paramedics were not on the list. Many services are reluctant or unwilling to participate in multidisciplinary case review because of perceived liability or discovery concerns.

For several years, we have advocated including peer review protection for EMS, enabling meaningful performance improvement activities as required elsewhere in Missouri law governing EMS agencies.

The resistance from the trial attorney's lobby has become predictable, suggesting peer review is used to hide wrong-doing or negligence despite ample case law to the contrary. HB 1980 (Cook-R, Phelps) passed the House, moved to the Senate, and successfully advanced through the Emerging Issues and Professional Registration Committee.

The 2026 session's efforts stalled at the same place, but I'm hopeful 2027 will finally be the year. We are currently working to bolster support, especially with the Senators who are most friendly to the trial lawyer lobby.

Finishing on a very positive note, research in injury care is flourishing. The Department of Surgery is a member of the LITES Network (Linking Investigations in Trauma and Emergency Services), a multi-center research collaborative headed at the University of Pittsburgh. The CAVALIER study is currently examining the use of calcium and vasopressin in the resuscitation of patients suffering from hemorrhagic shock, and notably is the first study to ever be done at the University of Missouri under the EFIC (exception from informed consent) process, a highly regulated option for emergency care research. In addition, the Department of Emergency Medicine's research group was awarded a $4.6 million-dollar Safe Streets and Roads for All grant from the US Department of Transportation in early 2026 to develop a regional advanced EMS response program, likely to include expansion of the currently limited pre-hospital blood products available for the severely injured. That group is also working closely with DHSS (and the Missouri Hospital Association) to pair EMS, trauma registry, and hospital data to shape a complete picture of emergency care. It's the first such effort attempted in Missouri, and we're very excited about the potential for future outcomes-based research. Trauma center leaders remain in frequent communication and are working to develop an informal TQIP® collaborative to identify and share best practices.

It's been a privilege to lead the Frank L Mitchell Jr, MD Trauma Center for the past 14 years and to be a member of the ACS Committee on Trauma – Missouri Chapter. I've made life-long friends and work alongside exceptional trauma care providers from across Missouri who not only provide excellent patient care but dedicate significant time and effort advocating for trauma system development at a high level. The future of trauma care is bright. With persistence, we can achieve great things while, as Dr. Mitchell often said, "keeping the patient at the center of everything we do."

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Robotic Surgery: Who Benefits More, the Patient, or the Surgeon?

by Thomas Xu, MD, Kevin Bartow, MD & Milot Thaqi, MD

Health Care

Robotic surgery should be best understood as a tool with the potential for value within the broader minimally-invasive modality.



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Abstract

The adoption of robotic-assisted surgery (RAS) across multiple specialties has outpaced procedural specific evidence of benefit over laparoscopy. The question we seek to answer is not whether RAS "works"—rather whether the purported advantages are primarily for the surgeon or the patient and under what circumstances those advantages justify the added cost and complexity. With the review of randomized, trials, large comparative cohorts, cost analyses, and ergonomic studies, we hope to highlight areas where RAS delivers patient-centered value compared to surgeon benefits. Across many routine operations, with well-performed laparoscopy, patient outcomes are largely equivalent, however operative time, cost, and emerging potential safety concerns highlight the importance of a measured approach to the spread of RAS. There is evidence that RAS does offer some benefits, namely in deep pelvic dissections. Surgical approach should be based on documented outcomes, surgeon proficiency, and surgeon benefits rather than being driven by platform availability alone.

Key Words

Robotic surgery, ergonomics, patient benefits, outcomes.

Introduction

Robotic-assisted surgery has evolved from a niche utility to now becoming routinely available and used across many hospitals and specialties. Utilization and adoption increased rapidly between 2012 and 2018 across multiple common operations, with seemingly no evidence of robotic-assisted procedure superiority to traditional laparoscopic procedures.[1] Similar patterns have been seen across many different hospital systems, including the Veterans Health Administration, where common general surgery procedures have seen an expanded adoption of the robotic platform.[2] This is clinically relevant because the adoption of this technology has occurred faster than the typical timeframe seen historically to allow for the establishment of patient benefit for each specific operation.

The expansion of the robotic platform exists within the economic realities of modern-day healthcare. Robotic programs require substantial capital investment, maintenance costs and per-case expenses.[3,4] Modern-day healthcare increasingly demands that technology adoption be

justified through value—clinical outcomes relative to costs across the patient's care.[5,6] Given this, the appropriate question is not whether robotic surgery can be performed safely, but rather whether there is a marginal advantage over well-established laparoscopic or open surgical techniques and in which clinical settings do the advantages of robotics justify its added cost and complexity.

The debate between traditional laparoscopic surgery and robotic surgery persists because the definition of what constitutes a "benefit" is multidimensional. For patients, benefits relate to clinically meaningful outcomes—complications, recovery time, durability and successful oncologic treatment when cancer is the indication. For surgeons, benefits can include improved ergonomics, physical workload, decreased occupational injury risk, and potentially increased career longevity. For health systems, the benefits of robotic surgery are usually framed within market competitiveness and improved value.[5,6] Leaders in surgical quality have explicitly called for safeguards in adoption of the robotic platform given its rapid growth; these safeguards include clearer evidence thresholds, structured implementation and outcome-based monitoring.[7]

This review evaluates the evidence supporting both sides of the central question—patient and surgeon benefit— while emphasizing the tradeoffs and implementation issues that determine real-world value. Our goal is not to position robotics as inherently advantageous or disadvantageous, but rather to define when robotic usage is and is not defensible and what governance is needed to minimize harm during its initial adoption.

Methods

A targeted literature review was conducted to identify evidence relevant to the comparative benefits of robotic-assisted surgery for patients and surgeons. The review addressed six domains: adoption trends, cost and value, comparative procedural outcomes, safety, surgeon ergonomics, and ethics/regulatory guidance. PubMed/MEDLINE served as the primary database. Additional sources included the Cochrane Library, the US Food and Drug Administration website, and selected society guidance documents, including SAGES resources.

Search terms included robotic surgery, robot-assisted surgery, adoption, diffusion, cost, value, ergonomics, learning curve, rectal cancer, cholecystectomy, bile duct injury, inguinal hernia, ventral hernia, and hysterectomy. This manuscript was designed as a narrative review rather than a formal systematic review. Priority was given to randomized trials, large comparative cohort studies, systematic reviews, meta-analyses, cost analyses, and regulatory or society guidance statements. English-language human studies were included. After reviewing relevance and study quality, 36 references were selected for analysis, including five randomized clinical trials, four large observational comparative studies, three systematic reviews or meta-analyses, six cost or value-focused analyses, four guideline or regulatory documents, and 12 additional foundational studies, editorials, or ethics-focused publications.

Evidence and Discussion

1. Procedure-Level Value Analysis

Robotic surgery is often framed as though it confers a global advantage. However, the literature does not support this blanket statement. Rather, the benefits conferred by robotics depends on the procedure as well as the operating surgeon. In some operations, the robotic platform may offer an incremental technical advantage that can translate into measurable improved patient outcomes. In other operations, the robotic platform has comparable outcomes as traditional laparoscopic techniques with increased operative times and higher overall costs. Because capital investment and operating costs are substantial with robotics, the burden of proof rests on demonstrating meaningful incremental value over laparoscopic techniques, not merely feasibility.[3,4,5,6]

The value of robotic surgery is context driven. In one context, this platform can be "high value," while in another it can be "low value." Since laparoscopy has been proven to be safe, efficient, and have excellent outcomes, robotics must demonstrate an incremental and measurable advantage in order to justify it as a substitution for laparoscopy. In instances when the anatomy is constrained or when the technical constraints of traditional laparoscopy are apparent, the benefits of robotics is more reasonable to justify.

2. When Patients Benefit More

Robotic Surgery in Rectal Cancer Treatment

One of the best contemporary arguments for robotics as it relates to a patient-benefit is for deep pelvic dissection, where visualization and wristed instrumentation help to facilitate precise dissection

and reconstruction. Early evidence in rectal cancer treatment did not establish clear superiority of the robotic platform versus traditional laparoscopy. The ROLARR trial found the conversion rate to open between Laparoscopy and Robotics was 8.1% and 12.2% in their cohort of 471 patients which was not statistically significant. Likewise, key short-term outcomes such as intraoperative complications, postoperative complications, 30-day mortality, bladder dysfunction, and sexual dysfunction were also not statistically significant.[8]

More recent evidence suggests that in selected settings and at experienced programs, robotic rectal operations for middle and low rectal cancer may improve clinical outcomes. The REAL trial, a prospective randomized control trial demonstrated improved macroscopic complete resection in the robot arm (95.% vs 91.8%) which was statistically significant. Furthermore they noticed improved gastrointestinal recovery, shorter postoperative hospital stay, fewer conversions to open surgery, less estimated blood loss, and fewer intraoperative complications in the patients that received robotic surgery versus traditional laparoscopy.[9] Importantly, the REAL trial three-year outcomes demonstrated improved oncological and functional endpoint benefits, with locoregional recurrent of 1.6% in the robot arm vs 4.0% in the laparoscopic arm which was statistically significant and suggests the possibility that the benefits of the robotic extends beyond the perioperative period.[10]

When looking both at procedures performed in urology (radical prostatectomies, partial nephrectomies, cystectomies, nephrectomies and lymphadenectomies) a meta-analysis performed in 2022 demonstrated that robotic surgery has improved patient outcomes across the procedures, including shorter length of stay, less blood loss, and fewer complications with noted increased length of the operation and associated cost of the procedure itself.[11] Similarly, a similar meta-analysis was performed in the gynecological literature which included over 479 studies, and found that robotic surgery was associated with shorter length of stay, lower pain scores, less blood loss, and lower conversion rates, and complications compared to laparoscopy.[12]

Expanded Minimally Invasive Access?

One argument that has been commonly raised in favor of adoption of the robotic platform is that it allows for the expansion of minimally invasive surgery to patients who would otherwise have to undergo open operations due to surgeon comfort with robotics compared to laparoscopy. The adoptions data highlights that with the expansion of robotics surgery, the number of traditional laparoscopy case decreases.[1,2] The substitution of traditional laparoscopy cases for robotic surgery typically has neutral or negative value when outcomes remain unchanged yet cost is much higher. Real value may be found if the rate of open operations decreases with the expansion of the robotic platform with reduction in morbidity and mortality and lower length of stay.

3. The Case That Surgeons Benefit More

The Ergonomic Advantage

Surgeon musculoskeletal strain is common in minimally invasive operations and has been described as a growing occupational health problem.[13,14] Robotic consoles are frequently promoted as an ergonomic solution, and empirical data supports a measurable reduction in physical demand in many contexts.[15] A systematic review focused on ergonomics similarly concluded that robotic surgery improved both objective markers of comfort, especially with muscle strain of the upper extremities, increased strain on the cervical spine, and perceived ergonomic benefits from numerous questionnaire based studies.[16]

While the physical ergonomic benefits have been well documented, the difference in mental workload has been less understood. The RIVAL trial, which assessed robotic versus laparoscopic inguinal hernia repair, found increased operative time and costs with robotic surgery and reported greater surgeon frustration in the robotic arm. The increased surgeon frustration is an important factor that is hard to quantify, and argues against the assumption that the robotic platform universally improves the surgeon experience in routine general surgery cases.[17]

Why Surgeon Benefit Matters

Ergonomics is a critical consideration in surgery because the physical demands of operative practice extend beyond simple discomfort and may influence surgeon performance, efficiency, and long-term career sustainability. Prolonged static postures, repetitive upper extremity movements, awkward positioning, and visual strain can contribute to musculoskeletal fatigue and chronic pain, particularly in the neck, back, shoulders, and upper limbs.[16] Over time, these issues may reduce operative stamina, impair concentration during complex

cases, and lead surgeons to decrease case volume or modify their practice patterns, thereby contributing to lost productivity. Perhaps more importantly, persistent occupational strain may threaten professional longevity by accelerating physical wear and limiting a surgeon's ability to maintain a high operative workload across a full career. Accordingly, attention to surgical ergonomics should be viewed not merely as a matter of comfort, but as an important component of surgeon performance, workforce preservation, and the long-term sustainability of surgical practice. A health system may reasonably value reduced occupational strain, but that benefit must be weighed against cost and patient outcomes, particularly when patient benefit is marginal or uncertain.[5,6]

4. Safety Concerns

Common Bile Duct Injury Concerns

The most consequential patient-centered outcome that should give pause for the rapid adoption of robotic surgery is the higher rate of bile duct injuries with robotic-assisted cholecystectomy as compared to laparoscopic cholecystectomy.[18] A subsequent analysis studied whether underlying differences in patient complexity explained the differences in bile duct injury rates between robotic and laparoscopic cholecystectomy. This study still found that there is an increased risk of bile duct injury even after accounting for differences in patient complexity.[19] Given the findings from these studies, experts questioned in what patient group robotic cholecystectomy provides added value relative to laparoscopic cholecystectomy.[20] In addition, the learning curve that is associated with the adoption of robotic-assisted cholecystectomy highlights that proficiency trajectories occur in real-world settings and may be discordant with patient safety.[21]

These findings are impactful because a bile duct injury is a highly morbid event with lasting consequences and substantial downstream costs. Historical and contemporary surgical literature has characterized bile duct injuries as both a clinical and financial disaster and has emphasized the need for prevent-oriented systems of care to minimize occurrences.[22,23] The increased risk of bile duct injuries with robotic cholecystectomy as compared to laparoscopic cholecystectomy does not prove that robotic cholecystectomy is inherently unsafe. It demonstrates that rapid diffusion of new technology into a high-frequency benchmark operation can expose patients to an adoption-phase risk without evidence-based patient benefit.

Guideline creation and structured safety programs are critical in the face of rapid increased use of the robotic platform. Multi-society guidance statements and programmatic initiatives emphasize safe cholecystectomy principles and operation standardization that can mitigate risk regardless of platform.[24, 25]

Oncologic Considerations: When "Minimally Invasive" Is Not Automatically Equivalent

The minimally invasive oncology literature reinforces that technique changes can have unanticipated consequences. In early-stage cervical cancer, a randomized trial demonstrated worse disease-free and overall survival with minimally invasive radical hysterectomy as compared to an open approach.[26] Additional observational studies have reported similar decreased survival associated with minimally invasive radical hysterectomy.[27] While the above data is not specific to robotics, it does serve to underscore the principle that minimally invasive techniques and technological advancement are not substitutes for disease-specific outcome validation. This should serve as a caution against enthusiasm for rapid robotic adoption in oncological operations before adequate comparative outcomes data.

5. Costs, Marketing, and Ethics: Why Implementation Affects Who Benefits

Randomized Trials in Hernia Surgery: Equivalence at Higher Cost

Inguinal and ventral hernia repair provide strong examples where high-quality evidence does not demonstrate clear patient-centered superiority in the debate of robotics versus laparoscopy. In the RIVAL study, robotic inguinal hernia repair did not improve clinical outcomes relative to laparoscopic repair, while increasing operative time and costs.[17] For ventral hernia repair, a multicenter blinded randomized controlled trial found no difference in postoperative hospital days and reported longer operative time and higher costs with robotic repair.[28] In the PROVE-IT trial that focused on patient-reported outcomes after ventral hernia repair with intraperitoneal mesh, patient-centered endpoints did not demonstrate a meaningful advantage for the robotic approach.[29] Collectively, these data support the conclusion that, in routine hernia surgery where

laparoscopic outcomes are already excellent, robotics frequently dilutes value by increasing resource use without improving outcomes.

Cost of Adoption

The initial capital costs for acquisition of a robotic platform as well as the operating costs are substantial. Due to this, the cost-effectiveness threshold is sensitive to operative time, utilization volume and reductions in complication rate or length of stay at a rate high enough to offset higher operating costs.[3,4] General surgery procedures utilizing a robotic approach have been analyzed and demonstrate higher costs in cholecystectomies and inguinal hernia repairs with an average increase cost of $650 to more than $1,300, while foregut cases were equivocal: supporting the need for careful selection for robotic utilization rather than the default minimally invasive approach.[30] These conclusions support value-based frameworks: if outcomes remain unchanged in the face of rising costs, value declines.[5,6]

Marketing and Its Effect on Patient Preference

Patient perception of robotics can be influenced by marketing. Marketing terminology such as "innovative, cutting edge, and state of the art" found a 31% chance of shifting patient preferences towards the robotic platform independent of differences in clinical outcomes.[31] An analysis of direct-to-consumer advertising found that promotional materials emphasize benefits while deemphasizing uncertainty and tradeoffs.[32] These findings should be incorporated into the informed consent process to discuss and disclose different approaches and their respective benefits and tradeoffs.

Ethical Considerations

A systematic review into robotic-assisted surgery highlights tensions introduced by organizational investment, conflicts of interest and the implications related to the principle of justice when introducing costly new technology when patient benefit is uncertain.[33,34] Regulatory guidance has cautioned against robotic approaches in oncologic procedures when safety and effectiveness has not been fully established, reinforcing that adoption of new technologies should not outpace evidence to support such adoption.[35,36]

Conclusion

Robotic surgery should be best understood as a tool with the potential for value within the broader minimally-invasive modality. The most consistent evidence supports surgeon-centered advantages across a multitude of different operations—reduced physical workload and improved ergonomics. However, this is not universally true for all surgeons, and these advantages do not independently equate to added value for the robotics platform.[13,15,16]

In select, technically constrained operations, the data supports robotics as providing meaningful improvements in patient outcomes including long-term oncologic and functional outcomes.[9,10] In contrast, data from common procedures such as hernia repair demonstrate clinical equivalence with higher operative time and costs.[17] Moreover, many contemporary studies raise the concern for a higher bile duct injury rate with the proliferation of robotic cholecystectomy—an outcome that should give pause to the rapid adoption of robotics for a procedure that has been performed safely with traditional laparoscopy for over two decades.[17-25,28,29] In the consideration of the setup of a robotics program, a number of different key points stand out that at this time are pragmatic and are supported by literature:

- Consider RAS in patient and procedure specific situations where comparative data supports its adoptions, an example being in low pelvic dissection for rectal cancer as reported in the REAL trial.[9,10]
- Refrain from defaulting to RAS in routine operations that have proven benefits in laparoscopy, especially when randomized trials demonstrate non-superiority, with higher cost such as in inguinal and ventral hernia repairs.[17,28,29]
- Adoptions and early learning curves should be tracked, to ensure patient safety as the priority, especially in procedures where serious complications have been documented, such as bile duct injury in cholecystectomies.[19-25]
- While ergonomic benefits are well documented, surgeon benefit should not be assumed, especially with workflow constraints.[13,15,16]
- Inform patients of the cost, and benefit uncertainty, while ensuring that alternatives are presented as equivocal.[31-34]

The decision for a robotic approach should

therefore be anchored in procedure-specific comparative data, calibrated to operator and program proficiency and coupled with longitudinal monitoring of outcomes, rather than being driven by platform availability alone.[5,6,17]

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The Great Debate: Metabolic Surgery vs. Glucagon-Like Peptide-1 Receptor Agonists in Managing Patients with Obesity and its Related Comorbid Medical Illnesses

by Andrew A. Wheeler, MD, Norbert Richardson, MD & Joshua Landreneau, MD

Health Care

Data is consistent that despite uncommon risks and long-term side effects, bariatric surgery is more effective compared to GLP-1 RA as monotherapy for treating obesity.



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Abstract

Obesity as a chronic disease continues to increase in prevalence despite continual advancements in surgical and medical therapy. Bariatric surgery has been the gold-standard for effective treatment of obesity and its related diseases for multiple decades. However, with the continual introduction of newer and more effective glucagon-like peptide one receptor agonists, the most effective non-surgical therapy to date, the debate has begun about which therapy is more effective in treating patients suffering from chronic obesity. As data continues to emerge, further consideration must be given regarding the use of these modalities as monotherapy or as combination therapy for treating obesity. We will provide arguments for each therapy and make a further argument for multimodal therapy to treat the challenging disease of obesity.

Key Words

Bariatric surgery, glucacon-like peptide one receptor agonist (GLP-1 RA), combination therapy, medical weight loss.

Introduction

Bariatric, or metabolic surgery, has been the mainstay as the most effective modality for treating obesity and its related comorbidities for many years. Multiple studies have demonstrated the superiority of metabolic surgery in managing obesity[1] and comorbidities such as diabetes mellitus,[2] hypertension,[3] and prevention of cardiovascular events[4] while even extending patient's life longevity.[5]

The first glucagon-like peptide one receptor agonists (GLP-1 RA) were developed in 2005 for the treatment of diabetes mellitus,[6] however significant weight loss was seen as a positive side effect when treating patients with diabetes. Approval for GLP-1 RA use was thus approved in 2015 for the treatment of obesity.[7] With newer medications achieving regulatory approval, level one evidence emerged demonstrating semaglutide and tirzepatide as effective treatment for not only diabetes but also obesity[8] and thus

these medications have moved to the forefront as non-surgical modalities that effectively treat obesity. This review will compare the effectiveness of GLP-1 RA to metabolic surgery, exploring the evidence for each modality in treating obesity and its related comorbidities then discuss the benefit of combined therapy in treating this difficult to manage disease.

Argument for GLP-1 Agonists

GLP-1 RA have rapidly gained in popularity in recent years as the obesity epidemic has now been met with a low-risk, non-surgical, medical option that provides effective therapy in treating obesity. First described in the treatment of diabetes mellitus,[6] the additional benefit of these medications in treating obesity has emerged with newer medications being developed and many more now in FDA trials. Within this class of medications, a wide range of effectiveness has been demonstrated. On one end of the spectrum, liraglutide has been shown to lead to 8% of body weight loss[9] with tirzepatide representing the highest percentage of weight loss of currently approved FDA medications at over 20% total body weight loss (TBWL).[10] Although some side effects have been described with GLP-1 RA at the highest doses including gastrointestinal side effects including nausea (31%), diarrhea (23%), constipation (5.8%), and dyspepsia (4.2%), rare serious side effects in a randomized controlled trial were documented in only 6.8% of patients.[10] Although surgery is traditionally seen as much higher risk, surprisingly the level of serious side effects are similar in bariatric surgery compared to GLP-1 RA, with major complications after surgery reported at 0.8-5.6% for patients undergoing sleeve gastrectomy and 1.4-9.4% in patients having a gastric bypass.[11] It is important for patients and prescribers both to understand however, that there is a significant rate of weight recurrence when GLP-1 RA medications are stopped. Studies have demonstrated patients who stop the GLP-1 RA can regain up to 70% of the weight they lost in the first year after stopping the medications.[12] Further complicating factors affecting the management of obesity with GLP-1 RA are frequent insurance coverage issues leading to lapses in therapy or requiring discontinuation of the medications altogether. Although the pharmaceutical industry's production issues with GLP-1 RA have largely improved, the medications are still quite expensive, precluding many patients from having access to these medications. Although recent efforts by the federal government may have led to lower costs of medications, as new medications come to market the challenges around pricing will undoubtedly continue. Thus, the long-term role of these medications in treating obesity will continually be redefined.

Argument for Surgery

Bariatric, or weight loss surgery, refers to a variety of surgical interventions for the management of severe obesity. While dietary modifications, lifestyle changes, and pharmaceutical options remain essential components of weight management, surgical interventions for obesity can result in robust and durable reduction of excess body weight for those who fail nonoperative weight loss interventions. Further, in addition to benefits in weight reduction, bariatric surgery offers profound therapeutic benefits for the treatment of obesity-associated medical diseases, beyond what can be achieved with maximal medical therapy.[13,14]

Bariatric surgery results in both substantial and sustainable weight loss in most patients. The extent of expected weight loss is dependent on the procedure performed and certain patient factors, which is beyond the scope of this article. However, in aggregate, greater than 90% of patients can expect to achieve at least 50% excess weight loss at two years following bariatric surgery, with 60% of patients maintaining this weight loss at ten years postoperatively.[15] This expectation in weight loss after bariatric surgery is significantly higher and more sustained than patients being treated with pharmacotherapy, including GLP-1 RAs. In a recent study comparing outcomes of bariatric surgery and GLP-1 RA therapy, patients undergoing either sleeve gastrectomy or Roux-en-Y gastric bypass surgery achieved 28.3% TBWL compared to 10.3% in the medically-treated cohort after two years.[16] Additionally, while

bariatric surgery has sustained efficacy, there is significant and expected weight regain in patients who discontinue GLP-1 RA therapy, with the majority of patients discontinuing pharmacologic weight loss therapy within one year.[17,18]

Superiority of Surgical Management of Obesity Related Comorbidities

In addition to demonstrated efficacy in producing sustained weight loss, bariatric surgery has significant efficacy in the treatment of weight related medical diseases. Bariatric surgery has been found to have significant benefits for glycemic control and remission of type 2 diabetes, superior to patients treated with maximal medical management, with results persisting at 12 years follow up.[19] These findings persist even in the GLP-1 RA era, with bariatric surgery associated with more favorable diabetes-associated outcomes when compared to GLP-1 RA therapy.[20] Bariatric surgery is further associated with a significant improvement in long-term cardiovascular disease outcomes, with superiority achieved with surgical management of obesity compared to GLP-1 therapy in preventing major cardiovascular events.[21,22] In a recent multicenter, randomized controlled trial, bariatric surgery was found to be far superior to lifestyle modifications and medical therapy for the treatment of non-alcoholic steatohepatitis (NASH), with greater than half of bariatric surgery patients achieving histologic resolution of NASH at one year.[23] Collectively, due to the overwhelming health benefits that bariatric surgery affords, mortality rates over 30 years after undergoing bariatric surgery has been found to be 49.2% lower than non-operative control patients with obesity, with greater than 6 years of increased life expectancy.[5]

Risks of Bariatric Surgery

Bariatric surgery is most commonly performed with a minimally invasive approach via a laparoscopic or robot-assisted platform. Due to refinements of surgical approach, improved postoperative patient care protocols, and vigorous national quality standards, bariatric surgery has become remarkably safe. The risk of death within 30 days of surgery for patients undergoing bariatric surgery is approximately 0.08%, less than more commonly performed procedures such as cholecystectomy or total hip replacement.[24-26] With the adoption of minimally invasive surgical techniques, convalescence following surgery is typically less than two days, with same-day discharge offered in certain patients at specialized centers. [27]

Cost Effectiveness of Bariatric Surgery

Finally, bariatric surgery is far more cost-effective and economically sustainable than obesity pharmacotherapy with savings of almost $12,000 when patients undergo bariatric surgery compared to two years of GLP1-RA treatment.[16] GLP-1 RA require continuous adherence, and due to the high cost of ongoing use, the "break even" point of cost reduction is on average nine months for sleeve gastrectomy and less than one year for Roux-en-Y gastric bypass when compared to GLP-1 RA.[28] Bariatric surgery patients also have far less health care utilization costs, including both inpatient and outpatient medical encounters, when compared to patients undergoing medically supervised weight loss.[16] Given the continued epidemic of obesity, from the perspective of both individual patients and population health, bariatric surgery remains undeniably cost-effective.

Despite significant advances in obesity medicine and weight loss pharmacology in recent years, current evidence continues to support the role of bariatric surgery for patients with obesity who have failed dietary and lifestyle management. Continued education of patients and providers as well as expansion of access to bariatric surgery is essential to maximize both patient outcomes and public health benefits.

Argument for Combination Therapy

Although bariatric surgery provides greater and more durable weight loss than GLP-1 RA, the combination of these two modalities are more effective than either independently.[29] However, the use of GLP-1 RA in the preoperative setting, routine postoperative setting, or only for nonresponders to or for weight recurrence

after surgery is not well known. Although more commonly described is their use in the postoperative setting to help augment postoperative weight loss, they can also be prescribed preoperatively to aid in weight loss prior to surgery to bring patients to a lower, safer preoperative weight.[30]

Preoperative Use of GLP-1 RA

Preoperative use of GLP-1 RA may be particularly beneficial in patients with a higher BMI who may be at increased risks of surgery secondary to their weight or comorbidities. Thus, GLP-1 RA may have a role in these patients to improve surgical candidacy, decrease complications and potentially aid in long-term weight loss. Ilanga, et al. demonstrated that patients with a BMI greater than 50 kg/m2 who were treated preoperatively with GLP-1 RA had greater preoperative weight loss than those who were not treated, without a delay to surgery or increased postoperative complications.[31] Mathur, et al. demonstrated that when used in the preoperative setting, patients lost more weight when taking GLP-1 RA, however, those patients actually lost less weight at 12 months post-surgery compared to patients naïve to GLP-1 RA therapy.[32]

On further analysis in this study, when comparing starting weight when GLP-1 RA therapy was initiated, rather than weight at time of surgery, medications plus surgery did have higher weight loss at 12 months although not reaching statistical significance. Thus, the additional preoperative weight loss achieved in patients on GLP-1RA may blunt the effect from surgery although the TBWL was not negatively affected. In contrast to this, Martines, et al. demonstrated lower weight at time of surgery and at 12-month follow-up in patients treated with liraglutide preoperatively.[33] AbuHasan, et al. performed one of the largest studies examining preoperative GLP-1 RA and showed that over a five-year period the use of these medications in the preoperative setting significantly increased, but their preoperative administration did not lead to postoperative differences in weight loss at one year postoperatively.[34] Thus, the use of preoperative GLP-1 RA has not been shown to definitively improve or impair long-term weight loss after bariatric surgery.

GLP-1 RA and Surgery for Obesity Related Comorbidities

Patients with type 2 diabetes may benefit most when treated with GLP-1 RA in the preoperative setting as these medications may lead to improved long-term control of diabetes compared to surgery alone.[35] Although no data exists examining the effect of GLP-1 RA in treating fatty liver disease preoperatively, in non-surgical patients, GLP-1 RA therapy was associated with a 62.9% remission rate of steatohepatitis.[36] Thus, it could stand to reason that when used preoperatively, GLP-1 RA may decrease liver size and thus help improve the efficiency and safety of bariatric surgery.

Postoperative Use of GLP-1 RA in Surgical Nonresponders

Surgical treatment failure occurs in greater than 20% of patients after gastric bypass, considered one of the most commonly and effective weight loss surgery procedures performed.[37] The use of medications to address weight recurrence and/or inadequate weight loss is thus of significant interest. The BARI-OPTIMISE trial enrolled patients with less than 20% TBWL at least 12 months post-bariatric surgery. This study revealed an additional 8.82% weight loss over 24 weeks with liraglutide versus 0.54% with placebo when used in the postoperative setting. The results were most pronounced in patients who had undergone a sleeve gastrectomy as well as patients with a higher baseline BMI. Significant additional metabolic improvements were noted with the additional weight loss including reductions in triglycerides, total cholesterol, LDL cholesterol, fasting glucose levels, total body fat, and hemoglobin A1c.[38] A meta-analysis evaluated the addition of GLP-1 RA medications in treating obesity in the post-bariatric surgery patient demonstrating significant additional TBWL at 12 months or greater (13.15% TBWL with semaglutide). As tirzepatide is a relatively newer medication, only three-month

data was available but demonstrated 15.5% TBWL with tirzepatide.[39] Despite these benefits, it must be understood by prescribing physicians and patients that patients treated with GLP-1 RA after bariatric surgery experience more adverse gastrointestinal side effects. According to one meta-analysis, common adverse events include nausea (23%), constipation (10%), vomiting (6%), diarrhea (6%) and abdominal pain (2%).

However, discontinuation medications due to adverse events occurred in only 3% of patients.[39] Kramer, et al. demonstrated similar rates of side effects but 7% of patients discontinued the medication due to these side effects.[29] These additional gastrointestinal side effects must be recognized by surgeons caring for these patients as these symptoms can also be indicative of significant long-term complications of bariatric surgery and cannot be ignored unless risking catastrophic outcomes. Also concerning is the risk of additional nutritional deficiencies and loss of lean mass with the additional weight loss secondary to GLP-1 RA. Both bone mineral density and lean mass were decreased in patients taking GLP-1 RA after bariatric surgery.[40] Loss of lean mass can further decrease a person's metabolic rate thus putting the patient at risk of weight loss stalls, and even weight recurrence when the medication is stopped for various reasons. Thus, patients must be actively managed by providers well experienced in bariatric surgery and the management of postoperative complications including nutritional deficiencies, given the significant long-term impact these complications and side effects can have on patient outcomes.

Although data continues to emerge regarding GLP-1 RA use in both the preoperative and postoperative setting, further data is needed. The long-term effects on weight loss in patients who take GLP-1 RA preoperatively and whether they continue or discontinue their use after surgery has not been fully elucidated. The combined use of these therapies given the constant changes in public and insurance policies that affect access to these medications will play a significant role as providers manage patients struggling with obesity and its related diseases.

Conclusion

Although both metabolic surgery and GLP-1 RA have been demonstrated to be effective therapies for treating obesity and its related comorbidities, data is consistent that despite uncommon risks and long-term side effects, surgery is more effective compared to GLP-1 RA as monotherapy for treating obesity. Nonetheless, patients that experience weight recurrence after surgery, multimodal therapy is indicated to treat resistant obesity. As additional and more effective medications emerge, the conversation will continue to evolve as to the role of metabolic surgery and anti-obesity medications as monotherapy or combined therapy as medical providers continue to combat the obesity epidemic. Regardless, this complex disease should involve collaborative efforts between bariatric surgeons and primary care physicians and other specialists to achieve optimal outcomes.

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Personalized Medicine In Complex Aortic Aneurysm Repair

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Health Care

Management of aortic aneurysms has evolved rapidly in recent history with a dramatic transition from open to endovascular therapy for simple aneurysms followed by a similar trend for complex aneurysms.



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Abstract

For patients with aortic aneurysms involving the visceral segment, historically, treatment options were limited and associated with major morbidity and mortality. More recently, an array of options have become available for these patients as a result of both refinements in perioperative management and evolution of endovascular devices and techniques.

This review aims to highlight the current options for treatment of complex aortic aneurysms including open, endovascular, and hybrid approaches. We emphasize the strengths and limitations of each that may allow surgeons to tailor the approach for each individual patient.

Keywords

Aortic aneurysm, endovascular aneurysm repair.

Background

Aortic aneurysm is a leading cause of death in the United States (US). Morbidity and mortality of aneurysm rupture remains high despite decades of advances in minimally invasive techniques.[1] Open surgical aneurysm repair underwent multiple iterations including ligation, plication, electro-thrombosis, and cellophane wrap until interposition grafting with synthetic conduit became established as the operation of choice in the mid 20th century.[2] Michael Debakey, MD, et al. reported on the clinical use of Dacron as a stable synthetic arterial substitute in 1958.[2] Subsequently, in 1974, Stanley Crawford published his series of 23 patients that underwent thoracoabdominal aneurysm repair, reporting one perioperative death, one patient with paralysis, and no instances of major renal or visceral ischemia.[3] Endovascular aneurysm repair (EVAR) was approved by the Food and Drug Administration (FDA) for use in abdominal aortic aneurysms (AAA) in 1999. Since then, endovascular technology has transformed the management of both intact and ruptured aneurysms, allowing for increased complexity with the introduction of fenestrated and branched devices (F/BEVAR).[4]

A study utilizing the National Inpatient Sample (NIS) from 2004 to 2015 found that the proportion of AAA treated with EVAR dramatically increased over this time, reaching 85% for intact AAA and 55% for ruptured AAA

by the end of the study period.[5] The overall mortality similarly decreased over this decade, from 2.8% to 1.6% for intact AAA and from 48% to 28% for ruptured AAA. A follow up study using NIS data from 2004 to 2019 showed that thoracoabdominal aortic aneurysm (TAAA) repair has followed the same trend with the proportion of endovascular repair shifting from 3.8% in 2004 to 72% in 2019 for intact AAA and 2.6% to 42% for ruptured AAA.[4] Mortality for both open surgical and endovascular repair remained markedly higher for TAAA than infrarenal AAA at 9.8% for intact TAAA and 45% for ruptured TAAA at the end of the study period. This difference underscores the fact that extensive aneurysms involving renovisceral branches continue to be challenging to manage in comparison to those that can be repaired with simple stent grafts. Careful planning and attention to a range of patient and anatomic factors are essential to providing optimal patient outcomes.

Open Surgical Repair

Open surgical repair entails a thoracoabdominal exposure and replacement of the aneurysmal segment of aorta with bypasses or reimplantation of renal and mesenteric branches as well as critical intercostal or lumbar branches. Operative approaches may vary. A number of adjuncts have been described to reduce the risk of ischemic injury including cardiopulmonary bypass for distal perfusion, cold renal perfusion, selective visceral perfusion, and cerebrospinal fluid drainage to mitigate the risk of spinal cord ischemia.[6] In 2016, Jospeh S. Coselli, MD, et al. published the outcomes of their three-decade single practice experience of 3,309 consecutive TAAA repair. Within this high volume environment, the overall rate of adverse events was 14% including 7% perioperative death, 3% stroke, 9% spinal cord deficit, 12% acute renal dysfunction, 26% cardiac and 36% pulmonary complications.[6] Independent predictors of adverse outcomes included advanced age and rupture. Contemporary reports from high volume centers demonstrate early mortality up to 33%, postoperative dialysis up to 17%, and persistent paraplegia up to 8%.[7] A recent study evaluating the implementation of a perioperative protocol for TAAA repair in 14 patients reported no perioperative mortality with 14% acute kidney injury, none requiring permanent dialysis, and spinal cord ischemia rate of 7% with no permanent paralysis.[8] These results suggest that it is possible to minimize the risks of open surgical repair by deploying strategies to minimize ischemia time, spinal cord protection, and judicious perioperative resuscitation. This continues to be relevant since there are a cohort of patients who do better long term with open surgery, such as younger patients (under the age of 65) or those with connective tissue disorders. There are also patients who may be ineligible for endovascular devices, such as those with an active infection or poor iliofemoral access. Although the durability of endovascular devices has improved, as EVAR has become more prevalent so has failure due to endoleak—some of these patients may also require open surgery for definitive repair.

Hybrid Repair

An alternative to standard open surgical repair is a hybrid approach with extra-anatomic visceral bypasses ("debranching") followed by exclusion of the aneurysm with a stent graft. This potentially reduces risk by avoiding thoracotomy, aortic cross clamping, and need for cardiopulmonary bypass. Although this technique was initially promising, outcomes were not markedly better than open repair with the caveat that it was typically reserved for sicker patients. A multicenter European study evaluated 107 cases of planned hybrid repair and reported perioperative mortality of 15% with spinal cord ischemia in 12% and 26% requiring at least temporary hemodialysis.[9] A 2016 study compared hybrid repair (n=81) to open TAAA repair (n=84) and found comparable outcomes including 10% perioperative death, 7% paraplegia or paraparesis with higher rate of new dialysis requirement (14.8% for hybrid vs. 3.6% for open repair).[10] Furthermore, 12% of patients required reintervention for endoleak. While the patients who underwent hybrid repair were older with more severe co-morbidities, these data suggest that abdominal debranching followed by endograft placement still carries a major physiologic insult without the durability of open repair. Nevertheless, these techniques remain useful in select circumstances. For example, aberrant renal anatomy can occur in up to 30% of patients and complicates endovascular repair. In situations where major renal branches cannot be preserved with fenestrations or branches, bypass from the iliac artery may facilitate EVAR (Figure 1).

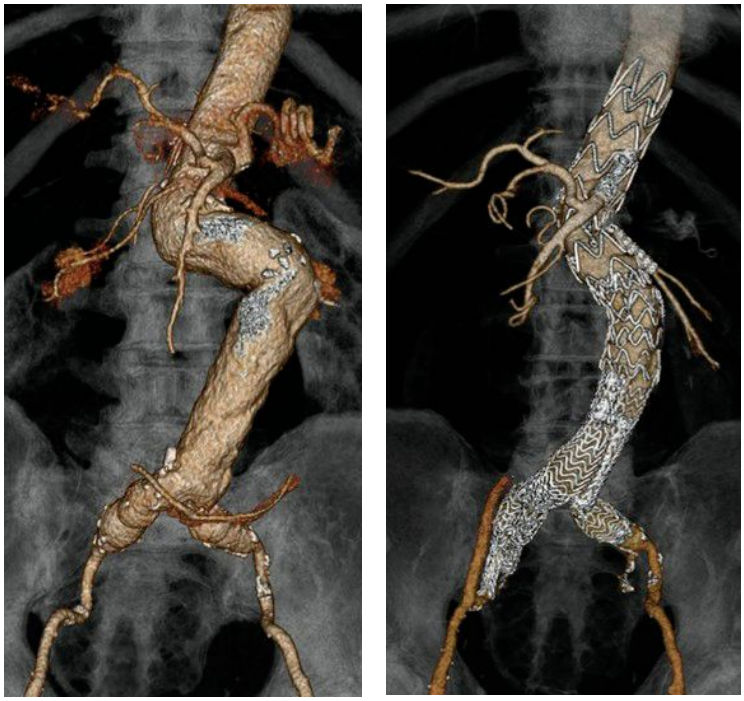


Figure 1. Hybrid staged repair of pararenal aneurysm with complex renal anatomy including largest right renal artery originating from aortic bifurcation. Repair included coil embolization of splenic artery and accessory renal branches, right renal artery open debranching from external iliac artery, and physician modified branched endograft.

Fenestrated/Branched Endografts and Commercially Available Devices

F/BEVAR has been performed within investigational contexts since the early 21st century.[11] Fenestrated endografts have holes in the stent graft to allow flow to aortic side branches that may or may not be spanned with a bridging stent. A branched endograft has self-expanding covered stents attached to the primary stent graft for each target vessel. The first FDA approved fenestrated device is the Cook Zenith™ Fenestrated Endovascular Graft (ZFEN), which was approved in 2012. This device is indicated for juxtarenal aneurysms and allows for up to three fenestrations manufactured for patient specific anatomy. This is not feasible for emergent cases as it requires weeks of manufacturing time. Results from the pivotal trial incorporating 67 patients and 178 visceral arteries showed high technical success (100%) with low perioperative mortality (1.5%).[12] In terms of durability, 22% required secondary intervention within five years, though 60% (9/15) of these interventions were for renal stent stenosis that may since be mitigated with transition from bare metal to covered bridging stents. Long term studies of fenestrated endografts have shown low long term aneurysm related mortality (2% at eight years) for both juxtarenal and type IV TAAA.[13] Comparative studies evaluating fenestrated vs. open repair have redemonstrated the perioperative benefit with similar long term mortality outcomes.[14]

Over two decades after endovascular TAAA repair was first reported, the first off-the-shelf device was approved by the FDA in 2024 with the Gore Thoracoabdominal Multibranch Endoprosthesis (TAMBE) (Figure 2). The associated prospective multicenter trial showed favorable safety and efficacy at one year.[15] In 102 patients with type IV TAAA or pararenal aortic aneurysms, one year freedom from all-cause mortality was 94% with one device-related and one procedure-related death. The most common adverse event was target vessel occlusion in 14 (15%) patients, primarily renal arteries. Risk factors included renal artery diameter ≤ 5mm and pararenal aneurysm. Early review of real-world cases shows high technical success rate with no perioperative mortality and similar rate of reintervention (15%).[16] This held true despite 76% of these patients not meeting criteria for on-label use due to chronic dissection, previous failed endograft, contained rupture, and other factors. Long term follow up is still needed to assess durability of this technique.

Customized Devices

In highly selected patients, excellent procedural and aneurysm-related outcomes have been demonstrated for F/BEVAR. Unfortunately, until recently, outside of a small number of centers with access to custom manufactured devices under investigational device exemptions (IDE), there were no approved devices for patients who do not fit the strict anatomic criteria of ZFEN. Off-label customized solutions have disseminated to fill this gap.

Physician-modified endograft (PMEG) involves modification of commercially available stent grafts on the back table by the operating surgeon. This is highly versatile since fenestrations or branches corresponding to individual patient anatomy can be added along the length of the endograft.[17,18] If



Figure 2. Repair of large symptomatic extent IV thoracoabdominal aortic aneurysm using off-the-shelf TAMBE device. TAMBE was chosen because of iliac and visceral tortuosity as well as large diameter within visceral segment.

needed, this can be done urgently using off-the-shelf simple stent grafts. Outside of IDE sites, PMEG has emerged as the preferred technique for elective repair of complex aneurysms, accounting for over 60% of cases nationally.[19] This approach has been critiqued for limited quality control. Small errors in placement of fenestrations can lead to misalignment with target vessels that can have devastating consequences. Modifying the endograft may also impact its structural integrity with implications for long term durability. These potential risks have been surmountable with training and experience from high volume centers.[20] The group from Beth Israel Deaconess Medical Center found no difference in perioperative or long term outcomes between PMEG and ZFEN despite PMEG being used to repair more extensive aortic aneurysms.[21] Advancements in techniques, such as reinforcing the fenestrations to prevent leak between components and use of steerable sheaths, have contributed to improved procedural success and outcomes. On the other hand, these cases can be challenging in the setting of severe visceral aortic tortuosity, iliac tortuosity, or visceral artery stenosis, which can each compound the complexity of the case.

An alternative way to custom modify a graft is via laser in-situ fenestrated endograft (LIFE). In this technique, an off-the-shelf simple stent graft is deployed across the visceral segment and fenestrations created using a laser catheter based on pre-stenting or pre-cannulation of visceral vessels for guidance. In case series, technical success rates range from 94% to 100% with higher rates of failure with visceral artery stenosis or high degree of angulation.[22] LIFE is useful for treatment of symptomatic or ruptured aneurysms as it may be faster in achieving aneurysm exclusion.[23] Similar to PMEG, this utilizes commercially available devices but, unlike PMEG, this does not require precise alignment of fenestrations since they are made in-situ. The reported rate of reintervention has been high at 28 to 56%. [23] This may reflect the emergent nature of a large proportion of reported cases. Long term studies are needed to assess durability and target vessel patency.

As more devices come to market, the need for these customized solutions will change as FDA-approved devices for complex endovascular repair are prioritized. However, there are still benefits to PMEG over TAMBE or ZFEN, for example in allowing for incorporation of four visceral vessels while limiting aortic coverage. Customized devices will still have a role going forward for certain anatomic considerations and emergent cases, though the applicability and limitations still need to be defined.

Conclusion and Future Directions

Complex aortic aneurysms pose a weighty challenge for patients and physicians. Open surgical repair was historically the gold standard for treatment, but even at centers of excellence, this confers high risk of morbidity and mortality. There is also a significant proportion of patients who are not candidates for open repair, increasing with an aging population. Multiple endovascular options have emerged including

commercially available ZFEN and TAMBE and modified solutions with PMEG and LIFE. None of these have been shown to be clearly superior in terms of long term outcomes. More likely, each has a role in treatment of a certain subset of patients.

In our practice, we have been able to offer all of the currently available options and aim to tailor a treatment plan to individual patient and anatomic characteristics. This involves meticulous preoperative planning using software for multiplanar reconstruction and centerline measurements. We benefit from collaboration including review and execution of complex cases between multiple vascular surgeons and multidisciplinary effort with cardiac surgery colleagues. Shared decision making with patients and their families is also critical and involves considerable education to work through the complexities of a given approach. Often, the diagnosis of a complex aneurysm is the start of a long-term relationship both prior to surgery and in long term surveillance.

Management of aortic aneurysms has evolved rapidly in recent history with a dramatic transition from open to endovascular therapy for simple aneurysms followed by a similar trend for complex aneurysms. Ideally, additional devices will come to market in the US to allow for on-label treatment of a broader range of anatomy as are available in Europe. Further granular studies are needed to compare outcomes between different endovascular approaches and elucidate which is best for each patient. Multiple AI-assisted algorithms have been developed to facilitate precise planning and surveillance. These still need to be refined and have not yet been broadly adopted for use. Together, each of these components will help improve care for patients with this challenging clinical problem.

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History and Evolution of Lower Extremity Salvage

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Health Care

The future of microsurgery certainly is combining the fields of plastic surgery, orthopedic surgery, and vascular surgery to produce the best results for a wide range of patients.



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Abstract

There has been a paradigm shift in the management of lower extremity injury from amputations to more complex limb salvage techniques. Despite advancements in orthopedic surgery, trauma surgery, plastic surgery, and vascular surgery, not every patient is a candidate for complex lower extremity limb salvage. For this reason, novel advancements in plastic and reconstructive surgery have targeted not only limb salvage but also functional amputations. Here we review the history and advancements in microsurgical limb salvage and lower extremity amputation to discern how today's surgeon can better aid this population.

Keywords

Limb preservation, lower extremity injury, orthopaedic surgery, microsurgical.

History of Limb Trauma

The management of lower extremity trauma is a continually evolving area of research with its early beginnings stemming from times of unrest and war. Lower extremity amputations were one of the earliest medical procedures to be performed. Management preceding the 18th century was extremely limited and focused largely on hemostasis. This period saw the implementation of ligatures for direct hemostasis and the first documented use of tourniquets during amputation.[1] By the 19th century and the American Civil War, amputations became the single most common surgical operation performed. This led to the development and innovation of prosthetic devices. The 20th century gave rise to modern anesthesia, allowing surgeons to perform more complex and technical procedures. Additionally, surgeons incorporated aseptic techniques and debridement of wounds.

In 1912, Alexis Carrel won the Nobel Prize for his innovations in vascular surgery. Importantly, he developed the triangulation technique for suture repair of blood vessels (anastomosis).[2,3] Prior to his advancement, the suture repair of blood vessels often led to blood clots or even fatal hemorrhage. Improving anastomotic technique has laid the foundations for organ transplantation, vascular surgery, and microsurgical free flap surgery that is routine today.

Another pivotal change in the management of lower extremity trauma came in 1960, with the introduction of the operating microscope for use in free flap surgery. Free tissue transfer, or a "free flap" is a surgical procedure that involves transferring healthy tissue from one part of the body to another area for coverage of an acquired defect. The blood vessels between the donor and recipient sites must be anastomosed requiring microsurgery techniques. Although the use of tissue flaps for soft tissue repair had been documented throughout history, this era saw a revolution in reconstructive surgery through the rapid development of microvascular techniques.

When considering free flap surgery in the setting of trauma, the surgeon must first determine if the patient is a candidate for such a procedure. In 1976, the Gustilo-Anderson classification was developed.[4] This classification provides surgeons with a prognostic framework to aid in decision making for the treatment of open fractures. However, this system does not address the question of limb amputation vs. salvage, and still today no single classification system has proven itself infallible in determining which patients should pursue amputation vs. free flap reconstruction.

History of Amputation vs Salvage

While patients and physicians desire to preserve the affected limb whenever possible, limb preservation does not always lead to the best functional outcome for the patient. In 1987, Dr. Sigvard Hansen of Harborview Medical Center in Seattle voiced concern of the futility of trying to salvage Gustilo type IIIC tibial fractures (open fracture with vascular injury).[5] The article reports that in type IIIC fractures limb salvage can result in lengthy hospital stays, financial burden, and may ultimately result in a secondary amputation at a later date. This editorial was a call to action for the development of evidence-based guidance that can help clinicians counsel patients on the treatment choice that best optimizes both short and long-term function—limb preservation versus amputation.

In response to concerns of limb salvage futility, many authors have attempted to create algorithms for guiding the decision making between amputation and limb salvage. In 1990, Johansen and colleagues proposed the Mangled Extremity Severity Score (MESS) which examined the variables of 1) skeletal/soft tissue injury, 2) Limb Ischemia, 3) Shock and 4) age to determine who was suitable for limb salvage vs amputation.[6] A retrospective analysis and prospective trial found that a MESS score greater than or equal to 7 was an indication for amputation 100% of the time. However, there has since been a discussion of the limitations of the study. Some believe that with subsequent surgical advancements, many limbs with a MESS score greater than 7 are now salvageable.

The Lower Extremity Assessment Project (LEAP) represented a further milestone in the limb salvage vs amputation literature discussion. The LEAP study was a National Institutes of Health–funded, multicenter, prospective observational study which sought to delineate variables which might make a patient better suited for amputation vs limb salvage.[7] The LEAP study did not provide an algorithm to follow, but rather defined characteristics of the individual patients, their injuries, psychological profiles, demographics, functional status, and more. The main outcome measure was the Sickness Impact Profile, which is a multi-dimensional score of health status and function. The authors concluded that at two years, outcomes after reconstruction are equivalent to those of amputation. They found that in both groups, only about half of patients had returned to work. This trial highlighted that one of the only variables to impact outcome was "self-efficacy" which was defined as an individual's belief that they will resume usual life activities after their injury.

Findings from the LEAP trial and further research have helped to dispel some of the concerns raised by Dr, Hansen regarding the futility of limb salvage. The LEAP trial demonstrated that reconstruction is associated with higher risk of complications and more additional surgeries than amputation, as Dr. Hansen alluded to. However, the concern that patients undergoing lower extremity reconstruction for trauma are at a high risk of delayed amputation has not been supported in the literature.[8] Although cost should not dictate the

decision between limb salvage and amputation, the perception that salvage is more expensive often serves as a primary argument against it. However, this was challenged by the LEAP study in 2007 which found that the projected life-time costs for the amputation group were three times higher than the limb salvage group.[9]

While the LEAP study examined civilian adults, the Military Extremity Trauma and Amputation/ Limb Salvage(METALS) Study retrospectively examined the differences between lower extremity amputation and limb salvage in service members deployed to Afghanistan or Iraq between 2003-2007.[10] METALS suggested that amputation may lead to superior outcomes in the military population when compared to limb salvage. As this data contradicts data provided by the LEAP study, it is important to note the differences in population between these two studies and the differences between combat and civilian trauma.

In conclusion, no single treatment algorithm has been universally validated to mandate amputation over limb salvage. Ultimately, the decision remains a highly individualized process, requiring comprehensive shared decision-making between the patient and the multidisciplinary care team. While long-term outcomes for civilians may be equivocal as shown by the LEAP trial, a physician should determine a patient's long-term and short-term goals, social support, and self-efficacy. Patients should be counseled that limb salvage demands more upfront time investment from the patient than amputation. While the LEAP trial did not answer the specific call to action set by Dr. Hansen, it did provide many helpful data points to aid in the discussion between patient and physician.

Recent History and Advancements in Amputation

Not every patient is a candidate for limb salvage, but there is some consensus when a patient should undergo amputation. Typically, a warm ischemia time of >6 hours; threat to life; and unrepairable vascular injury are considered absolute contraindications to limb salvage. Regarding the level of amputation in lower extremities, the most distal level possible should be considered as energy expenditure during ambulating is inversely proportional to the remaining limb length.[11] It is preferable to keep the knee joint whenever possible, and a free flap can be used for soft tissue coverage if needed to preserve the knee joint.

Many recent advancements in lower extremity amputation have focused on addressing residual nerves, with the goal of reducing phantom limb pain and residual limb pain. The earliest treatment of nerves was in the form of traction neurectomy. Traction neurectomy applies tension to the nerves prior to resection, allowing them to retract farther from the weight bearing surfaces of the stump. Despite traction neurectomy, amputees frequently experience residual limb pain, phantom limb sensation, and phantom limb pain, with reported incidence rates ranging from 45% to 85%.[12-18]

Recent research has revolved around providing transected nerves with distal reinnervation targets. Dr. Gregory Dumanian and Dr. Todd Kuiken are credited with pioneering targeted muscle reinnervation (TMR) from Northwestern University in 2002. TMR was first created to allow upper extremity amputees to use myoelectric prosthetic devices. Later, it was discovered that these patients appeared to have less symptomatic neuromas and less phantom limb pain. This was demonstrated by a prospective, randomized clinical trial of 28 amputees in 2019 showing that TMR was associated with decreased phantom limb pain.[19] TMR surgery is now utilized following amputation with transected mixed motor-sensory and/or isolated sensory nerves surgically transferred to nearby motor nerve branches within the residual musculature. Further investigation has identified other surgical techniques that can also be useful to limit post-amputation nerve pain. This includes utilizing regenerative peripheral nerve interfaces (RPNI) and vascularized denervated muscle targets (VDMT). RPNI and VDMT differ from TMR in that the recipient target for the transected nerve is denervated muscle instead of coaptation to another nerve. However, all three techniques share the common goal of preventing aberrant nerve signaling by redirecting transected nerves to new targets.

Despite advancements in prosthetics, patients can be deterred from prosthetics due to skin breakdown, wounds, and pain. Osseointegrated prosthetics were designed to help reduce some of these complications. Osseointegrated prosthetics involve placement of a titanium rod anchored into the residual bone. The external rod then protrudes through the skin and connects to the prosthetic device. While the external rod is a risk factor for infection, several studies have noted improved mobility and more frequent usage of a prosthetic with osseointegration. [20,21]

Additionally, research in Agonist-Antagonist Myoneural Interface (AMI) amputation is ongoing with the goal of improving proprioception and bidirectional communication with prosthetic devices. [22] AMI is a surgical technique that reconnects pairs of opposing muscles (agonists and antagonists) after limb amputation, helping prosthetic limbs move more naturally and restoring a sense of limb position and control.

Recent History and Advancements in Lower Extremity Reconstruction

Early management of limb salvage patients includes early aggressive debridement and bony stabilization. An early pioneer in lower extremity reconstruction was Marko Godina. In his 1986 paper, he advocated for free flap coverage of lower extremity wounds within the first 72 hours after injury.[23] His paper hypothesized that due to vessel fibrosis, there are lower rates of flap failure and post-operative infection when free tissue transfer happens within the first 72 hours. This has been an area of vehement debate in literature. Many newer studies have shown equivalent flap outcomes and complication rates in flaps that were performed subacutely (10-15 days), and even in some cases further delayed (>21 days), compared to the first 72 hours.[24-26] These findings are often attributed to recent advances in wound care, improved surgical debridement, coordinated planning with definitive fixation, as well as the advent of negative pressure wound therapy.[27] However, most surgeons and research agree that flap coverage should ideally be performed as soon as possible after appropriate debridement and definitive bony fixation.

Godina made other notable contributions to the field of microsurgery, such as his advocacy for end-to-side arterial anastomosis in free flap reconstruction.[28] In his 1979 paper, he notes how even with vessel size discrepancy, end-to-end anastomosis was still the preferred technique by majority of surgeons at the time. Now, it is well accepted that end-to-side anastomosis is a suitable technique not only for vessel size discrepancy but also to preserve distal blood flow in patients who may only have a singular functioning vessel.

Further, anatomic research and cadaver studies have created what reconstructive surgeons know today as a robust reconstructive ladder of options for bone, muscle, and soft tissue coverage. The reconstructive ladder refers to a mental framework of options for limb restoration ranging from simple to the most complex. Interestingly, the introduction and popularity of the more straight forward pedicled perforator flaps came after that of free flaps in 1989.[29] Pedicled perforator flaps allow the underlying muscle to be preserved, and the skin and subcutaneous fat is kept alive by a vascular tributary coming off a deeper source vessel. The vascular tributary is never divided, and thus no microsurgical techniques are needed. In 1991, the propeller flap, which is a perforator flap isolated on its perforator vessel and rotated 180 degrees, followed as another way to provide lower extremity wound coverage without microsurgical techniques.[30]

The era of pedicled flaps provided surgeons with more reconstructive options, and these flaps have many advantages. Pedicled flaps can result in shorter operative times, can be performed with basic surgical equipment, and replace "like with like" tissue. However, pedicled flaps are not for every patient. A patient may still require a free flap due to their injury location, to provide healthy tissue outside the zone of injury, or due to defect size. In particular, the distal third of the leg has traditionally been an area where local flaps can be unreliable, and many surgeons will opt for free tissue transfer in this location.

Advancements have led patients with nerve injury or a singular vessel foot, who would have previously not been candidates for limb salvage, to pursue limb salvage should they desire.

The absence of plantar sensation is no longer a reason to exclude limb salvage. Bosse et al. noted in his 2005 study that more than half of patients who present with an insensate foot will regain sensation at two years. [31] In addition, research in the realm of nerve grafts for peroneal or posterior tibial nerve injuries in the setting of lower extremity reconstruction has demonstrated successful outcomes.[32] If there are damaged blood vessels, techniques such as the previously discussed end-to-side anastomosis or vein grafts can be employed to make free flap reconstruction still possible. Involvement of vascular surgery colleagues has proven that revascularization and free flap surgery can be performed in the same patient safely.[33] The future of microsurgery certainly is combining the fields of plastic surgery, orthopedic surgery, and vascular surgery to produce the best results for a wide range of patients. [34] the best results for a wide range of patients.[32]

Limb Preservation Today

Today, at the University of Missouri, we currently have a robust, growing team of specialists comprising our Limb Preservation and Optimization Team including six orthopedic trauma surgeons; three orthopedic microsurgeons; two plastic surgery microsurgeons; one health psychologist; a nursing patient coordinator; and clinical research specialists. Multiple studies have demonstrated that multidisciplinary limb salvage programs reduce major amputation rates and improve wound healing, limb salvage, and survival. [35-37]

To track limb optimization outcomes, the orthopedic surgery department created a prospective registry to collect patient demographics, surgical history, complications, and patient-reported outcome measures. Patients are enrolled in the registry following their first interaction with the Limb Preservation and Optimization Team and are followed for the duration of their life. Patients are not excluded from the registry due to a history of diabetes, smoking, or peripheral vascular disease.

Some of today's goals for the Limb Preservation and Optimization team are increasing awareness and access for TMR. The Limb Preservation and Optimization Team is becoming increasingly involved in TMR- with 23 procedures occurring in 2024 alone. With increased awareness of TMR, the hope is that TMR can be performed earlier. While it is preferred for TMR to be performed in the acute or subacute period after an amputation, TMR procedures have also provided patients with pain relief years after amputation.

Today, the decision for amputation versus limb salvage continues to be a complex one. It continues to be that not every patient is best suited for limb salvage- even if advancements have made this technically possible. Regardless of whether limb salvage or amputation is ultimately performed, the objective of the Limb Preservation and Optimization Team is to optimize functional outcomes while minimizing the number of required operative interventions through a coordinated multidisciplinary approach.

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The Future is Small: Little Patients, Big Leaps, Innovations in Pediatric Surgery

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Health Care

Every innovation, from robotics to AI-guided care, reflects the same principle that has guided our field since its inception: that every child deserves a chance at a healthy, fulfilling life.



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Abstract

Pediatric surgery stands at the forefront of technological innovation. The future promises even greater transformations, from robotics and 3D-printed models to non-operative management for traditionally operative surgical conditions. These developments are not merely technical triumphs; they represent a fundamental reimagining of how we diagnose, operate, and care for our smallest patients. In this article, we will examine emerging innovations transforming the future of pediatric surgery and the challenges they pose.

Key Words

Pediatric surgery, minimally invasive surgery, robotic surgery, telesurgery.

Introduction

Pediatric surgery has always existed at the intersection of technical ingenuity and delicate surgical care. Our patients are not just "small" adults; they present unique anatomical, physiological, and developmental considerations that demand tailored surgical strategies. Over the past few decades, advances in minimally invasive surgery, perioperative care, and imaging have revolutionized pediatric outcomes. Yet, the next wave of innovation promises to reshape the field even more profoundly. The future of pediatric surgery will be defined by how we harness technology to make it less invasive, more personalized, and globally accessible. The question is no longer if innovation will transform pediatric surgery, but how.

Minimally Invasive Surgery, Robotics, and Telesurgery

One of the most significant frontiers in pediatric surgery is the refinement of minimally invasive and robotic systems. The evolution from standard laparoscopy to flexible, wristed robotic instruments has enabled unprecedented precision in confined spaces. Robotic-assisted surgery offers several benefits, including superior 3D visualization, elimination of hand tremors, enhanced surgeon ergonomics, and improved instrument dexterity, particularly for complex reconstructive surgeries. The challenge, however, remains scale. Current robotic platforms were designed for adults, and adapting them for neonatal and infant anatomy requires engineering innovation and cross-disciplinary collaboration. Many robotic systems still have large camera scopes or ports (e.g., many

platforms have 8 mm or 12 mm scopes), which may be too large for very small infants. One such robotic innovation for pediatric surgery is the Senhance® Surgical System (SSS), developed by Asensus Surgical. It offers a reusable instrument portfolio with 3 mm and 5 mm instruments. According to an observational study on the use of the SSS for robotic-assisted surgery in pediatric patients, the research, conducted between 2020 and 2023, aimed to evaluate the safety and feasibility of the SSS for abdominal procedures in children aged 0 to 17 years, weighing more than 10 kilograms. The results, based on 42 cases, indicate a high success rate (90%) and low complication and conversion rates, supporting the implementation of the SSS in pediatric surgery due to its features, such as smaller instruments and ergonomic benefits for surgeons. The authors concluded that the SSS provides a safe and feasible option for minimally invasive surgery in children, addressing limitations found in other robotic systems designed primarily for adults.[1]

Another technical innovation in pediatric robotic surgery is telesurgery, also known as remote surgery, a branch of telemedicine that enables the performance of surgical procedures requiring a surgeon's expertise, even when the surgeon and patient are located at a distance, using robotic systems and telecommunications technology. Srivastava et al.[2] evaluated the feasibility, safety, and efficacy of remote telesurgery using the dual-console SSI Mantra Surgical Robotic System, the first surgical robot developed in India. The study involved both an animal experiment and clinical trials with five human patients, in which expert surgeons performed various procedures remotely via a secure, high-speed fiber-optic network. A crucial finding was achieving a low mean transmission latency (40–50 ms) and minimal data packet loss, both of which are vital for ensuring precise control and patient safety during remote operations. Ultimately, the successful outcomes, including nominal blood loss and no reported complications across all trials, validate the system's potential to expand surgical expertise remotely to various locations.[2]

3D Printing and Patient-Specific Surgery

Three-dimensional printing has evolved from a novelty to a vital tool in pediatric surgical planning for complex tumors such as neuroblastoma and Wilms tumors. Three-D models allow surgeons to visualize and rehearse individualized operative strategies. A recent systematic review investigated the utility of 3D printing technology in the preoperative assessment of children with extra-cranial solid tumors. The authors performed a comprehensive search across multiple medical databases to analyze current evidence, ultimately including eight studies involving thirty children with various tumors, such as Wilms' tumor and neuroblastoma. The findings suggest that 3D printed models are invaluable because they provide pediatric surgeons with a precise topographic view and a "sense of touch," which is superior to the two-dimensional nature of conventional radiological imaging for surgical planning and understanding complex spatial relationships. Furthermore, these models significantly enhance doctor–patient communication by improving parental understanding of the tumor and the planned management strategy.[3]

Beyond planning, the development of patient-specific implants and bioresorbable scaffolds offers hope for anatomically matched repairs that grow with the child. As bioprinting advances, the ultimate goal is within sight: constructing functional tissue, such as airways, intestines, or even kidneys, engineered from the patient's own cells, thereby eliminating rejection and the lifelong burden of transplantation.[3] One such example is the pioneering work by Atala et al.[4], which has demonstrated the feasibility of creating patient-specific organs using principles that overlap with modern 3D printing and tissue engineering.[4] In a landmark clinical study, autologous bladder constructs were generated by harvesting a small bladder biopsy, isolating urothelial and smooth muscle cells, and expanding them *in vitro*. These cells were then seeded onto a biodegradable, bladder-shaped scaffold tailored to the patient's anatomy, functionally analogous to a three-dimensional printed construct. After a period of maturation, the engineered bladder tissue was implanted, often with omental coverage to support vascularization.[4]

Clinical outcomes in pediatric patients with neurogenic bladder showed improvements in bladder capacity, compliance, and storage pressures, without the metabolic and mucosal complications associated with traditional bowel-based augmentation. This work provided one of the earliest proofs of concept that patient-specific, bioengineered organs could be constructed and successfully implanted in humans.

Although not yet widely adopted in routine clinical practice due to ongoing challenges such as vascular

integration, innervation, and long-term durability, this approach represents a critical step toward integrating 3D printing technologies with regenerative medicine. It highlights the potential for truly personalized surgical reconstruction, where autologous cells and custom-designed scaffolds may eventually replace conventional techniques that rely on non-native tissues.

Fetal and Regenerative Surgery: Treating Disease Before Birth

Fetal surgery remains one of the most extraordinary frontiers of pediatric innovation. It involves performing therapeutic interventions on the fetus before birth to correct life-threatening or debilitating congenital anomalies. Conditions such as myelomeningocele, congenital diaphragmatic hernia, and twin-to-twin transfusion syndrome (TTTS) can now be addressed *in utero* using open, fetoscopic, or minimally invasive techniques. An ongoing clinical trial is currently assessing the feasibility of fetal repair of complex gastroschisis via a fetoscopic surgical approach, evaluating maternal, fetal, neonatal, and infant outcomes in a cohort of 10 patients. The hypothesis is that *in utero* repair of gastroschisis will reduce postnatal mortality and morbidity in complex GS infants with minimal maternal and fetal risk (Clinical Trial ID NCT 05704257).

Advances in maternal-fetal imaging, anesthesia, and perioperative monitoring have improved survival and long-term outcomes. The principle is early intervention to prevent progressive fetal damage, rather than repair irreversible injury after birth. Collaborative care through multidisciplinary fetal therapy centers is essential for success and maternal safety. Techniques once considered unimaginable, such as repairing spina bifida or reversing renal anhydramnios *in utero*, are now life-saving realities.[5] One of the greatest success stories in modern pediatric surgery is fetal surgery for spina bifida patients. Patients with spina bifida (myelomeningocele) are at risk of lifelong neurological disability if untreated. Historically, repair occurred after birth, but irreversible spinal cord injury often occurred *in utero* due to prolonged exposure of neural tissue to amniotic fluid and mechanical trauma. The breakthrough came in the landmark Management of Myelomeningocele Study (MOMS) trial, published in 2011, which was the first randomized controlled trial comparing prenatal (fetal) vs postnatal repair. The results were extraordinary: those undergoing fetal repair required significantly less ventriculoperitoneal shunting (40% vs. 82%), exhibited improved motor function, and demonstrated an increased likelihood of independent ambulation at 30 months, as well as a reversal of hindbrain herniation in the majority of patients undergoing fetal surgery.[6,7] They also demonstrated better bladder function, mobility, and cognitive outcomes compared to those repaired after birth. As a result, despite the increased risk of preterm delivery and maternal uterine complications, fetal repair became the standard of care in selected cases, establishing a new paradigm in congenital anomaly management.

The next generation of fetal interventions will rely on miniaturized endoscopic systems, advanced imaging, and regenerative therapies that can correct disease before birth. These breakthroughs not only expand surgical capabilities but also challenge long-held boundaries among obstetrics, neonatology, and pediatric surgery, ushering in an era of collaborative, preemptive care.[8]

Global and Ethical Imperatives

Innovation must also be equitable. The technologies shaping pediatric surgery often arise in high-resource environments, yet the majority of children requiring surgical care live in low- and middle-income countries. The "future" of pediatric surgery will only be realized when these advances, tele-mentoring, affordable simulation, portable imaging, and low-cost robotics, are accessible globally. Ethical frameworks must evolve in tandem with technological advancements, addressing data privacy, informed consent, and the application of AI in decision-making processes for vulnerable populations.[9,10]

Expanding Role of Non-Operative Management in Traditionally Operative Pediatric Surgical Conditions

The landscape of pediatric surgery is evolving toward less invasive and more individualized care. Conditions once considered unequivocally surgical, such as appendicitis, intussusception, and specific trauma scenarios, are now being managed successfully without an operation in carefully selected patients. This paradigm shift reflects improvements in imaging, antibiotics, multidisciplinary care, and our growing understanding of disease biology. We will review key conditions in which non-operative management

(NOM) has gained acceptance, the evidence supporting these approaches, and the challenges that remain in balancing innovation with safety.

Traditionally, pediatric surgeons have been trained to cure through incision. Yet, the last two decades have witnessed a deliberate re-examination of that philosophy. Advances in diagnostics, critical care, and interventional radiology have expanded the range of conditions that can be managed without surgery. The concept of "non-operative first" is now being tested in conditions once viewed as unequivocal indications for operative intervention.

This shift is not about doing less; it is about doing what is necessary, based on sound evidence and individualized risk assessment.

Acute Appendicitis: Antibiotics Alone for Select Patients

Non-operative management (NOM) didn't start in academic hospitals: it started on submarines where surgeons weren't available.[11] It was during World War (WW) II in the United States Navy that the use of antibiotics in war environments led to occasional attempts to use NOM for acute appendicitis.[12] NOM became policy during combat patrols during WWII after three appendectomies were performed with difficulty on board ship by non-physicians using non-surgical instruments.[11] The policy persisted during wartime and into the Cold War, with NOM failure rates of 11%–15%.[11] As a result, NOM for uncomplicated appendicitis is among the most studied shifts in pediatric surgery. Multiple randomized controlled trials and meta-analyses have demonstrated that antibiotic-only therapy can be safe and effective in selected children without perforation, abscess, or appendicolith. Short-term success rates range from 70–90%, although recurrence occurs in 15–25% of cases within a year.[13,14] The key challenge lies in identifying which patients will benefit most from conservative therapy and ensuring shared decision-making with families who prioritize non-invasive options.

Intussusception: A Model of Non-Operative Success

Perhaps the most successful non-operative approach in pediatric surgery is the treatment of intussusception, first reported in 1927 using barium enema under fluoroscopic guidance.[15] This has progressed to pneumatic or hydrostatic enema reduction, guided by fluoroscopy or ultrasound, achieving success rates of 80–90% and thereby obviating the need for surgery in most cases, a standard of care prior to this innovation.[15] This model illustrates how enhanced imaging, timely diagnosis, and collaboration with radiology can improve outcomes while reducing surgical morbidity.[16]

Trauma: Historical Review of and Evolution of Non-operative Management of Blunt Abdominal Trauma in Children from Laparotomy to Observation

In pediatric trauma, especially blunt abdominal injury, NOM has become the standard for stable patients with solid organ injuries. Advances in imaging, hemodynamic monitoring, and interventional radiology have allowed for successful observation or selective embolization of splenic, hepatic, and renal injuries. This approach preserves organ function, reduces the need for transfusions, and minimizes unnecessary laparotomies, a profound cultural shift from the era of mandatory exploratory surgery.

Before the 1970s, blunt abdominal trauma in children, especially involving the spleen or liver, was routinely treated with exploratory laparotomy and splenectomy. Mortality from post-splenectomy sepsis in children, however, raised concerns about this approach. Until the 1960s, operative management was the standard for all solid organ injuries. However, the late 1960s saw the recognition of overwhelming postsplenectomy infection (OPSI), described by King and Shumacker in 1952, prompting efforts to preserve the spleen whenever possible.[17]

The major paradigm shift began at Primary Children's Hospital in Salt Lake City, where Douglas J. Upadhyaya and colleagues published pioneering work demonstrating that children with blunt splenic injury could be managed safely without surgery if hemodynamically stable.[18] Then, in the late 1970s, this extended to blunt hepatic injuries.[19] By the 1980s, hemodynamic stability, rather than injury grade, became the key determinant for NOM. By the late 1990s, advances in CT imaging and pediatric intensive care monitoring enabled accurate diagnosis and safe observation, with multicenter studies confirming high success rates (>90%) for NOM of spleen and liver injuries, leading to broader adoption of NOM in children.[20,21] In the modern era, NOM is now the standard of care for most hemodynamically stable

pediatric patients with blunt abdominal trauma, including high-grade injuries, with adjuncts such as angiographic embolization when needed.[22]

In summary:

- Pre–1970s: Routine laparotomy and splenectomy.
- 1968: Landmark shift to nonoperative management of splenic trauma.
- 1970s–1980s: Extension to hepatic and renal injuries.
- 1990s–2000s: Validation by multicenter and guideline studies.
- Present day: NOM is standard for hemodynamically stable pediatric blunt solid organ injuries.

Necrotizing Pneumonia and Empyema

Beyond the abdomen, similar trends are emerging. Pediatric empyema treatment has undergone a significant paradigm shift; once routinely treated by thoracotomy or video-assisted thoracoscopic surgery (VATS), it is increasingly managed with chest tube drainage and fibrinolytics, with excellent outcomes.[23] Historically, empyema in children was treated with open thoracotomy and decortication, which was considered the gold standard for achieving complete evacuation of purulent material and re-expansion of the lung. With advances in minimally invasive techniques, VATS has gained popularity as a less morbid alternative, offering improved visualization, shorter hospital stays, and reduced postoperative pain.[24] However, accumulating evidence over the past two decades has demonstrated that many cases of pediatric empyema can be effectively managed without surgery.[25] The use of chest tube drainage combined with intrapleural fibrinolytic therapy such as tissue plasminogen activator (tPA) has emerged as a highly effective first-line treatment.[25] Randomized controlled trials and meta-analyses have shown that this approach achieves high rates of treatment success, comparable to VATS, while avoiding the risks associated with general anesthesia and operative intervention.[26-28]

This shift reflects a broader trend toward stepwise, less invasive management. Current practice in many centers now favors initial treatment with antibiotics, chest tube placement, and fibrinolytics, reserving surgical intervention for cases that fail medical management or present with advanced organized empyema. Overall, the evolution in treatment underscores an evidence-based transition toward minimizing invasiveness while maintaining excellent clinical outcomes in children with thoracic empyema.

Adhesive Small Bowel Obstruction

Another evolving frontier is the management of adhesive small bowel obstruction. Traditionally managed operatively after 24–48 hours without resolution, many pediatric centers now extend conservative management with nasogastric decompression, Gastrografin challenge, and close observation, avoiding surgery in 60–70% of cases.[29] Thereby, reducing the risks of anesthesia, inadvertent enterotomy, and further adhesion formation. Over time, accumulating pediatric and adult data have demonstrated that a substantial proportion of adhesive obstructions resolve without surgery. This has led to a shift toward prolonged and carefully monitored conservative treatment. The management of adhesive small bowel obstruction in children has similarly evolved toward a more selective, nonoperative-first strategy.

Spontaneous Pneumothorax

Historically, the most common treatment for a child presenting with spontaneous pneumothorax is chest tube drainage, sometimes progressing to surgical intervention. However, the insertion of a chest tube is often painful and can cause injury, bleeding, and infection. Insertion of a chest tube usually involves hospitalization, with a reported mean length of stay of four days in patients with a first presentation with spontaneous pneumothorax.[30] However, a recent multi-center, randomized trial examining patients with moderate-to-large primary spontaneous pneumothorax found that conservative management (i.e., no chest tube) resulted in a lower risk of serious adverse events and, more importantly, pneumothorax recurrence, as well as a shorter length of hospital stay, compared to the chest tube interventional group. This landmark study challenges the long-standing dogma that initial chest tube drainage is necessary for all patients with primary spontaneous pneumothorax.[30]

Role of Pediatric Nursing in the Care of Pediatric Surgical Patients

Pediatric nurses play a central role in the holistic care of surgical patients, providing comprehensive medical care, emotional support, education, and

advocacy. Their role ensures not only physical recovery but also addresses psychosocial well-being, contributing significantly to the overall patient experience and outcome. From preoperative preparation to postoperative recovery and discharge planning, pediatric nurses provide critical clinical surveillance, family-centered support, and coordination of care that directly influence surgical outcomes. Preoperatively, pediatric nurses contribute to risk reduction through comprehensive assessment, patient optimization, and education of both the child and caregivers. Age-appropriate communication and psychological preparation have been shown to reduce perioperative anxiety, improve cooperation, and facilitate smoother anesthetic induction and recovery.[31,32] In the intraoperative and immediate postoperative phases, pediatric nurses play a key role in patient safety through vigilant monitoring, early recognition of clinical deterioration, and adherence to standardized protocols such as surgical safety checklists.

Implementation of nurse-driven safety initiatives, including those aligned with the World Health Organization Surgical Safety Checklist, has been associated with significant reductions in morbidity and mortality.[33] Postoperatively, nursing care is central to enhanced recovery and the prevention of complications. Pediatric nurses lead efforts in pain assessment and management using validated age-specific tools, early mobilization, and nutritional support. Effective pain control not only improves patient comfort but also reduces the risk of complications such as atelectasis and delayed recovery.[34] Furthermore, nurses are often the first to detect early signs of complications such as surgical site infections, ileus, or sepsis, enabling timely intervention. Education provided by nurses at discharge has been shown to reduce readmission rates and emergency department visits, particularly in complex surgical populations.[35] This is especially relevant in pediatric surgery, where recovery often continues at home and relies heavily on caregiver competence and confidence. In summary, pediatric nurses are essential collaborators in pediatric surgical innovation, bridging the gap between clinical practice, research, and education. They play an integral role in high-quality pediatric surgical care.

Education and Training

Pediatric nursing education begins in the classroom, with many programs adopting flipped classroom models that transform traditional lectures into hands-on activities, preparing students for real-world experiences. Nursing education has shifted toward active, case-based learning to strengthen critical thinking and clinical judgment. Simulation learning has also advanced, incorporating high-fidelity manikins that replicate surgical scenarios and allow future nurses to practice monitoring and delivering excellent patient care in a safe, controlled environment.[36]

Adapting to Surgical Innovation

As pediatric surgery evolves toward less invasive procedures, pediatric nurses must be skilled in individualized care, providing continuous education to patients and families about expectations while employing exceptional monitoring for subtle changes that may require adjustments to the care plan. Today's pediatric nurses care for increasingly complex patients using advanced, new-age devices, requiring ongoing learning and expertise. Success in this dynamic environment depends on partnering with peers and leaders to embrace innovation and master the future of pediatric surgical care.

Evidence-Based and Collaborative Practice

Modern pediatric surgical nursing now follows evidence-based protocols, including Enhanced Recovery After Surgery (ERAS) and perioperative best practices, integrating up-to-date research into care delivery. These protocols emphasize family education, early mobilization, and opioid-sparing pain management, all of which rely heavily on nursing leadership and collaboration across the surgical team.

Institutional Innovation: The MU Children's Hospital Experience

At MU Children's Hospital, these innovations are not theoretical; they are actively reshaping clinical pathways, training paradigms, and patient outcomes. As pediatric surgery enters an era defined by precision, technology, and individualized care, institutions such as University of Missouri must continue to balance innovation with ethical stewardship and equitable access to ensure that progress benefits all children.

In the realm of robotic surgery, more than 70 pediatric robotic procedures have been performed. This growing experience has facilitated expanded minimally invasive options for children in mid-Missouri and surrounding regions, while simultaneously serving as a platform for resident and fellow education in advanced surgical technology.

The evolution toward selective NOM is similarly reflected in institutional protocols. A structured antibiotic-first pathway for uncomplicated appendicitis has been implemented, with 20 patients treated to date. Two patients ultimately required appendectomy, one occurring more than one year after initial antibiotic therapy, yielding an early success rate of 90%. These outcomes align with emerging national data supporting carefully selected NOM strategies and underscore the importance of shared decision-making and longitudinal follow-up.

Innovation at MU also extends to quality improvement and clinical research. A recent quality improvement initiative evaluating suture type in laparoscopic gastrostomy was accepted for presentation at the 2026 meeting of the American Pediatric Surgical Association in Chicago, reflecting ongoing institutional commitment to optimizing procedural outcomes through data-driven practice refinement.

In addition, MU has initiated a multi-center randomized controlled trial investigating sham feeding in neonates with gastroschisis. This study examines whether early oral sensory stimulation can accelerate the return of bowel function, shorten hospital stay, and reduce healthcare expenditures for a condition historically associated with prolonged hospitalization and increased hospital expenditures. Such work exemplifies how innovation in pediatric surgery increasingly encompasses perioperative physiology, recovery optimization, and value-based care.

Furthermore, advanced imaging technologies have further enhanced preoperative planning and anatomical visualization at MU Children's Hospital. Here, pediatric radiology uses Syngo.via platform with TeraRecon 3D visualization software from Siemens Healthineers, to generate high-resolution 3D reconstructions. Siemens Healthineers' syngo.via is an intelligent, AI-powered imaging software platform designed for multi-modality 3D reading, advanced visualization, and reporting.[37] These models allow for improved spatial understanding of complex anatomy and facilitate surgical planning for congenital anomalies and other challenging pediatric conditions. The integration of advanced imaging into routine clinical workflows represents an important step toward more precise and individualized surgical care, while also enhancing interdisciplinary collaboration between radiology and pediatric surgery.

Finally, our Fetal Intervention Center has initiated fetal surgical interventions, with two cases performed to date. Ultrasound guided drainage of a very large fetal ovarian cyst was successfully performed with no membrane complications and with delivery of a healthy baby at term. This intervention has allowed normal pregnancy to ensue and avoid emergent surgery in the neonate. Moreover, fetal shunt placements were performed in a fetus with bilateral effusions and mediastinal shift saving this fetus from hydrops physiology which is a harbinger of fetal demise. While early in development, this effort represents an expansion of multidisciplinary collaboration among fetal surgeons, maternal-fetal medicine, neonatology, anesthesiology, and pediatric surgery, signaling institutional commitment to earlier intervention for select congenital conditions.

Together, these initiatives demonstrate how technological advancement, evidence-based non-operative strategies, quality improvement, and translational research are actively shaping pediatric surgical care at MU. These experiences reflect not only the adoption of innovation but also participation in defining its responsible implementation.

Conclusion

With the growing acceptance of non-operative strategies, this reflects a broader shift toward precision pediatric surgery, where intervention is tailored to the child, not the textbook. NOM has become an integral component of modern pediatric surgical care. The challenge ahead is to continue defining its boundaries through evidence-based practice while maintaining the core surgical principles of vigilance, safety, and compassion. The successful pediatric surgeon of the future will be one who is as skilled in selective restraint as in technical mastery.

The future of pediatric surgery is small in size but enormous in potential. Every innovation, from robotics to AI-guided care, reflects the same principle that has guided our field since its inception: that every child deserves a chance at a healthy, fulfilling life. As technology transforms what is possible, our challenge as surgeons is to ensure that compassion, equity, and curiosity remain at the heart of every leap forward.

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Highly Pathogenic Avian Influenza H5N1 in Missouri: Current Situation and Pandemic Potential

by David S. McKinsey, MD, Joel P. McKinsey, MD, Vincent A. Ait Ouamara, MPH, Molly Baker, MPH, Jessica Goswitz, MPH & John Bos, MPH

Future influenza pandemics, the timing of which cannot be accurately predicted, are inevitable.



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Abstract

Highly pathogenic avian influenza (HPAI) H5N1, which has caused severe disease in poultry since 1996, has become panzootic in wild birds and recently has spread to dairy cattle and other mammalian species in the United States. Although few human cases have been reported, devastating HPAI H5N1 poultry outbreaks and massive die-offs in wild birds and in some mammals raise concern about pandemic potential. Surveillance, early detection, public health interventions, farm biosecurity measures, and next-generation vaccines may reduce the risk of a future HPAI H5N1 pandemic.

Key Words

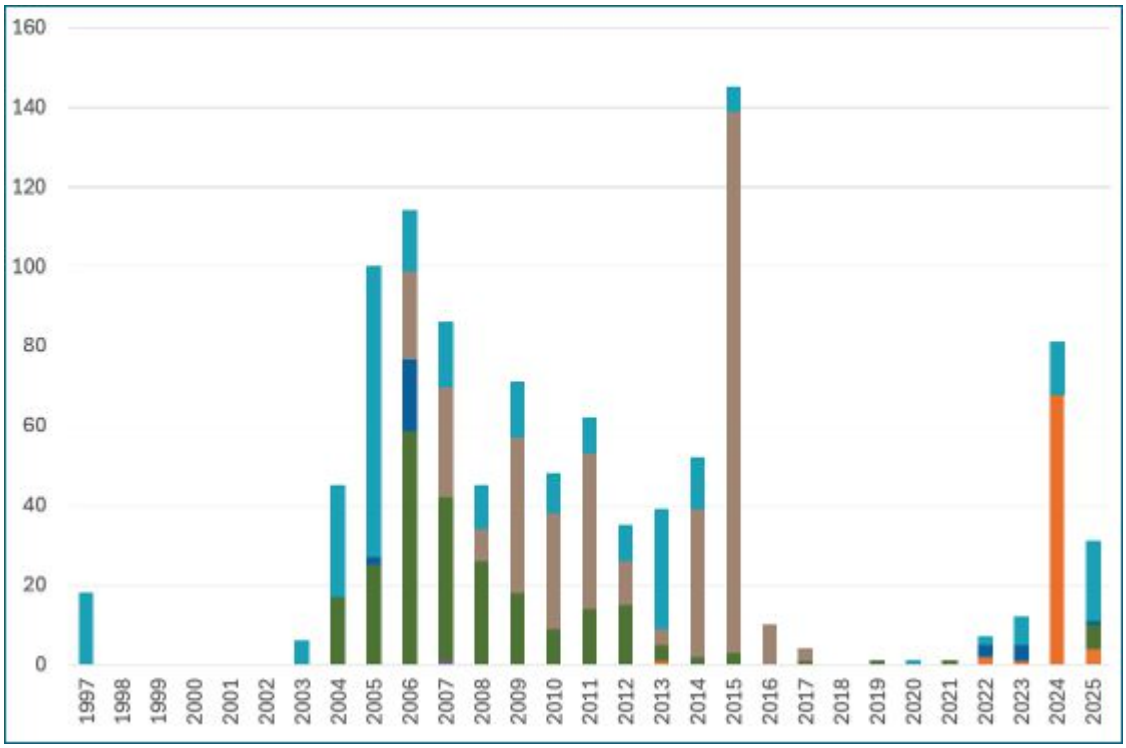
H5N1, avian, influenza, pandemic.

Influenza Viruses: Structure and Nomenclature

Influenza viruses produce the surface glycoproteins hemagglutinin (H) and neuraminidase (N), which are antigenically variable and are the dominant antigens triggering both the innate immune response to infection and protective antibodies induced by infection and vaccination. These viruses are categorized by type (A, B, C, or D) and subtype, defined by their specific H and N combinations. To date, 19 Hs and 11 Ns, all antigenically distinct, have been identified.[1,2,3,4] Influenza A subtypes gradually accumulate point mutations in the genes encoding H and N through antigenic drift, and differentiate into lineages and sub lineages called clades and subclades, based on diversity in the gene sequences that encode H. Subtypes, clades, and subclades are further characterized by viral genotype, determined by genome sequencing. Newer genotypes are called variants. Influenza A viruses circulate globally in multiple species including humans, pigs, poultry, and wild birds.[4,5]

A dramatic change in antigenicity, antigenic shift, periodically occurs among circulating clades or subclades by reassortment of genetic sequences of two different influenza A viruses coinfecting the same host.[6,7] In contrast to predictable influenza A and B seasonal epidemics each winter, influenza A pandemics occur at irregular intervals when newly reassorted viruses infect immunologically naïve persons, are virulent, and are efficiently transmitted from human-to-human.[6]

Figure 1. Global H5N1 Influenza Infections



Human HPAI H5N1 infections reported to the World Health Organization (WHO) since 1997 by WHO global region
Source: https://www.cdc.gov/bird-flu/php/surveillance/chart-epi-curve-ah5n1.html accessed 2/20/26)

Influenza Pandemics

Pandemics of influenza-like respiratory illnesses have been recorded since antiquity dating to 1580. Two large-scale epidemics or pandemics were described in the 1600s, five in the 1700s, and four in the 1800s.[4,6,8] Four influenza pandemics have occurred since 1900. The 1918 H1N1 pandemic, the worst in recorded history, caused an estimated 50 million deaths globally.[4,8,9,10] The 1957 H2N2 and 1968 H3N2 pandemics were less severe but also led to millions of deaths worldwide, whereas the 2009 H1N1 pandemic was more limited in scope.[1,6,7,9,10] Future influenza pandemics, the timing of which cannot be accurately predicted, are inevitable.

Emergence of H5N1 Influenza

A new HPAI H5N1 variant was identified in commercial geese in Guangdong, China in 1996.[1] A large outbreak of HPAI H5N1 in Hong Kong poultry the next year was associated with human infections and deaths.[1] Mass culling of poultry interrupted that epidemic but subsequently multiple new clades and genotypes of H5N1 have emerged.[1, 11] The geographic range and virulence of H5N1 have expanded, corresponding with the emergence of clade 2.3.4.4b after viral reassortment.[4,12] This variant has caused catastrophic infections in poultry and wild birds and recently has spread to dairy cows and other mammalian species, with a concomitant increase in the global count of human cases (Figure 1.)[10,11,13]

Natural Reservoirs and Other Affected Species

Migratory aquatic birds are the primary natural reservoirs of highly genetically diverse influenza A viruses including H5N1. Geese and ducks are the main carriers.[1,4,5,7,12] Global viral dissemination has been facilitated by bird migration along interconnected flyways, which has enabled waterfowl to introduce H5N1 to all continents.[1,4,10] Clade 2.3.4.4b was first introduced from Europe to Labrador in 2021 by seagulls and then spread rapidly throughout North America.[1,10]

Historically, H5N1 infections resulted in mild or asymptomatic infections in birds; however, new genotypes have caused high mortality in some

species.[12] Domestic chickens and turkeys consistently experience HPAI H5N1, characterized by rapid onset, severe disease, and sudden death.[4,7] Other wild bird species not historically affected by influenza viruses, including turkey vultures, eagles, hawks, and owls, also exhibit extreme vulnerability.[13]

Mild infections in tolerant migratory waterfowl create a concerning epidemiological scenario. Infected geese, ducks, and swans, which can shed high concentrations of virus in saliva, nasal secretions, and feces for extended periods while continuing their normal migratory patterns, have been a major driver of outbreaks in poultry operations.[4,12] Within a month after clade 2.3.4.4b was first detected in wild birds in the United States (US) in January 2022, infection spread to concentrated populations of commercial poultry, triggering many explosive outbreaks and resulting in substantial economic losses and a surge in egg prices.[4,10,12,14,15]

In 2022 efficient intra-mammalian transmission of H5N1 2.3.4.4b was documented for the first time in multiple wild and human-managed animal populations.[14] A lethal outbreak at a mink farm in Spain demonstrated evidence of efficient intra-species spread associated with a single viral mutation.[16] Wild marine mammalian species including sea lions and elephant seals, which have frequent contact with infected migrating sea birds and live in crowded colony structures, have experienced multiple mass mortality events.[4,10,17]

The reassorted H5N1 2.3.4.4b genotype B3.13, detected initially in March 2024 during a novel outbreak among dairy cattle in Texas, was linked to viral spillover from wild birds to cows.[14,18,19,20] Shortly thereafter, transported infected cattle introduced H5N1 into herds in multiple states.[21] Enhanced viral replication in the mammary tissues of infected dairy cows leads to high concentrations of viable H5N1 in their milk.[4] Pasteurization inactivates H5N1.[15,22,23]

H5N1 infections on farms have been reported in multiple peridomestic species including opossums; raccoons; foxes; and milk-lapping cats which have experienced fatal encephalitis. Mortality also has been documented in domestic cats which drank unpasteurized milk or consumed pet food containing raw turkey [22,24,25]

Ecological Dynamics on Farms

Farms offer multiple opportunities for zoonotic viral spread, raising concerns for pandemic potential of mammalian-adapted H5N1.[27] Poultry and cattle are at risk for H5N1 introduced to farms from external sources including migratory birds, fomites, cattle transported from other farms, or peridomestic species. [21,26,27] Fomite transmission can occur from equipment shared among farms, or from contaminated animal products. Less commonly, infected personnel may introduce H5N1 into a farm.[27]

Large open-air pens on cattle farms facilitate access of wild birds or mammals to shared, potentially contaminated feed and water.[28] High concentrations of H5N1 have been detected in wastewater streams and manure lagoons on farms; these contaminated bodies of water, often frequented by migrating birds, may serve as sources of infection for multiple bird and animal species.[26,28]

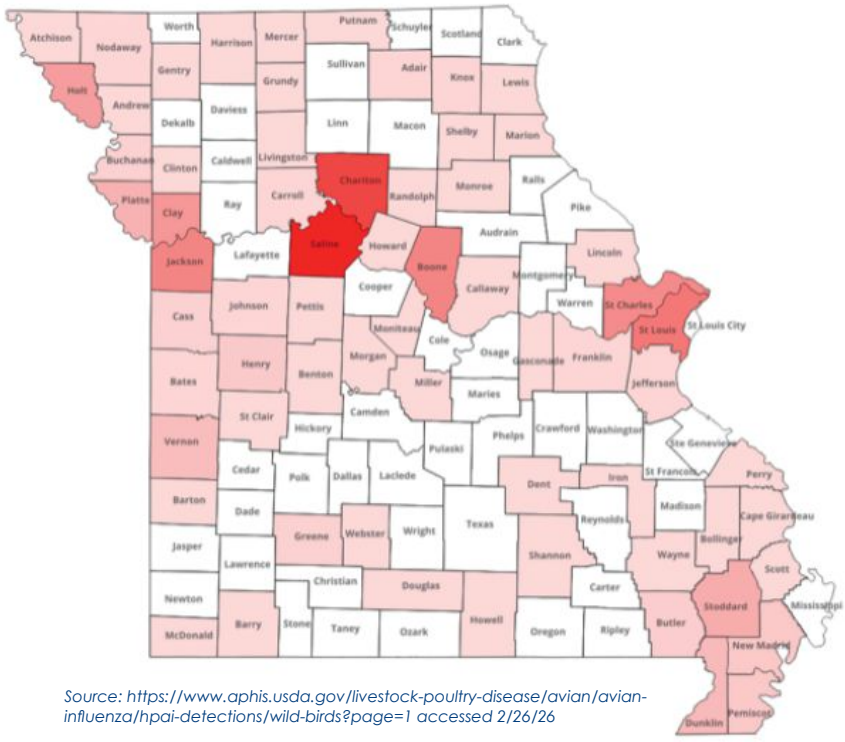
A study conducted at dairy farm milking parlors in California identified H5N1 in air, in cows' exhaled breath, and on several surfaces.[28] The use of high-pressure hoses creates the potential for viral aerosolization from contaminated milk.[26] Large fans in farm buildings also may facilitate airborne spread.[29] Spillover from dairy farms to poultry farms has been reported in several states. [18]

Missouri Data

As of March 2026, the US Department of Agriculture (USDA) and the Missouri Department of Conservation confirmed 536 unique HPAI H5N1 wild bird detections across 68 of Missouri's 114 counties[30] (Figures 2). These verified detections of HPAI H5N1 represent only a subset of birds affected during larger mortality events, as not all carcasses can be collected and tested. Between 2022 and 2025, multiple large die-offs involving hundreds of birds were identified throughout the state, indicating that the true impact and mortality associated with HPAI H5N1 in wild birds likely was substantially higher than the number of laboratory-confirmed cases. Additionally, surveillance detected H5N1 in mammals, two house mice, and four red foxes, in three separate counties.

Data from the Missouri Department of Agriculture highlights the propensity for HPAI H5N1 spillover events from wild bird populations to commercial poultry operations and backyard flocks. As of late 2025, Missouri recorded 60 HPAI H5N1 detections in human-managed poultry flocks across 27 counties.[31] These spillover events have necessitated aggressive containment measures, including extensive decontamination protocols and the depopulation of

Figure 2. HPAI H5N1 influenza detections in wild birds in Missouri counties through January 2026.



Source: https://www.aphis.usda.gov/livestock-poultry-disease/avian/avian-influenza/hpai-detections/wild-birds?page=1 accessed 2/26/26

over five million birds in 35 commercial flocks in the state as of April 1, 2026.[30] During this same period Missouri has reported no H5N1 detections in dairy cows, which comprise 2% of the state's cattle population, although H5N1 has been identified in herds in neighboring Oklahoma, Kansas, Nebraska, and Iowa.[32]

Human Cases

In the US from 2024 to early 2026, 71 human H5N1 infections were reported in 13 states including one case in Missouri.[15] Multiple high-risk groups have been identified, primarily poultry and dairy farm workers[15,22,33,34,35] (Table 1). Most of the confirmed cases have had confirmed animal or bird contact, often occupational; however, three persons, including the Missouri case, have had unknown sources of exposure.

Clinical manifestations have included conjunctivitis in approximately 90% of cases, fever in about half, respiratory symptoms in more than a third, and, less commonly, nausea and emesis.[33] Of note, one-third of cases have been manifested solely by conjunctivitis.[33] No cross-transmission in families, to suggest human-to-human spread, has been reported.[33,34] H5N1 disease severity generally has been milder than was observed in Asia between 1997-2016 although two fatal cases have occurred in the US.[15, 34] Thus, conjunctivitis or influenza-like illness in persons with suggestive exposure histories, especially poultry or dairy farm workers or persons who have had contact with sick or dead wild birds or backyard poultry flocks, should raise suspicion for H5N1 infection. The diagnosis also should be considered when PCR testing detects influenza A, but not the usual subtypes H1N1 or H3N2, given the possibility that the positive test result indicates presence of a novel influenza virus. [15]

To prevent delays in identifying H5N1 or other novel influenza viral infections in humans, the Centers for Disease Control and Prevention (CDC) recommends expedited subtyping of all influenza A specimens obtained from hospitalized patients and increased efforts by clinical laboratories to identify non-seasonal influenza viruses. If influenza A virus subtyping is not available at the treating facility, public health laboratories can perform routine virologic testing, a core component of the US National Influenza Surveillance Strategy. Influenza-positive specimens, especially those with un-subtypeable results, are actively sought by public health laboratories. This routine national influenza surveillance approach facilitated the detection of seven cases in the US, including the single Missouri case. [36]

Management of Human H5N1 Exposures in Missouri

The Missouri Department of Health and Senior Services (DHSS) coordinates surveillance and response efforts following human exposures to H5N1 in the state. The DHSS works with local public health agencies (LPHAs) to investigate exposures. LPHA personnel contact individuals to gather information about their exposures and symptoms. Public health professionals assess the extent of the exposure, educate the person about avian influenza, coordinate specimen collection and testing, and establish a monitoring period.[15] This public health response provides a resource for exposed

Table 1. Groups at High Risk for Exposure to H5N1 Influenza

- poultry farmers
- owners of backyard flocks
- dairy farmers in affected states
- exposure to sick or dead wild birds
- food processors working with raw milk
- veterinarians and animal health workers
- laboratory workers handling specimens
- health care workers in endemic areas

Sources: N. Engl. J. Med. 2025; 392: 843-54; https://cdc.gov/bird-flu/situation-summary/index.html

persons, enables rapid detection of cases of H5N1 after exposure, and helps to prevent potentially serious public health risks associated with spillover events, including human-to-human transmission.

If an exposed person develops symptoms within 10 days after exposure, the LPHA will work in collaboration with the DHSS Bureau of Communicable Disease Control and Prevention (BCDCP) to coordinate specimen collection and processing at the DHSS Missouri State Public Health Laboratory (MSPHL). Testing for H5N1 or other suspected novel influenza viruses must be pre-approved by contacting the DHSS BCDCP before specimens are collected and shipped to the MSPHL. Asymptomatic persons with higher-risk exposures may also be offered testing by the health department during public health investigations. CDC recommends testing individuals exposed to infected birds or animals who reported not wearing recommended personal protective equipment (PPE) or who experienced a breach in PPE adherence.[37] The testing protocol is outlined in Table 2.[15]

Treatment and Monitoring

CDC recommends initiation of oseltamivir as soon as possible for all symptomatic individuals who are confirmed, probable, or suspected cases of H5N1.[15] Oseltamivir post-exposure prophylaxis may be considered for asymptomatic people exposed to birds or animals infected with H5N1, particularly those who are pregnant or immunocompromised, or who have multiple comorbidities.[15] Exposed individuals who test negative should continue active monitoring for signs and symptoms of acute respiratory illness or conjunctivitis until 10 days after their last known exposures.[15]

Wastewater Surveillance

Serologic studies indicate that H5N1 infections in humans are underdiagnosed.[38,39] More extensive surveillance clearly is warranted. Wastewater surveillance for H5N1 is a newer tool for monitoring viral spread, although when results are positive the specific source of viral genetic material cannot be ascertained.[40] As of May 2026, H5N1 had been detected in wastewater in multiple states.[41,42] However, in Jefferson County, the only location in Missouri reported on the CDC dashboard, all wastewater tests have been negative, as have tests at sites near the state's western and southern borders. [42]

Prevention

Given the ongoing panzootic of H5N1 in wild birds, the lethality in commercial poultry, the increasing range of contaminated dairy farms, the risk for farm-to-farm spread, and the potential for a human pandemic, multiple aggressive prevention and control measures have been implemented by the agriculture industry and public health experts.

Farm workers may be exposed to circulating influenza viruses by humans, pigs, horses, or other mammals which shed influenza by sneezing and coughing; by avian species which excrete virus in saliva, nasal secretions, and feces; or by milk splashes or aerosols from infected dairy cattle.[4,10] Avoidance of unprotected contact with sick or dead poultry, wild birds, and farm animals and potentially contaminated environments is advised.[15,34] PPE, including eye protection and facemasks or respirators, is recommended when depopulating poultry flocks during outbreaks.[15, 27, 43] Although PPE use may be challenging in settings contaminated with dust and feathers, high adherence during depopulation has been observed.[26] Use of gloves, eye protection, coveralls, and boots is recommended at dairy farms in states where H5N1 has been detected, although high ambient temperatures during the warm weather months may limit adherence.[15,29,40]

The agriculture industry has established protocols for bio-exclusion (prevention of introduction of disease into a farm) and biocontainment (prevention of spread of disease within a farm or to other farms).[27] Bio-exclusion practices include establishing spray stations for vehicles; avoiding rendering dead birds at affected farms; bird and rodent-proofing; and limiting visitors.[27, 44] Farm workers may be

Table 2. Management of Human Exposure to H5N1

Signs and symptoms	Specimens
Respiratory symptoms	Nasopharyngeal and combined oropharyngeal/nasal swabs
Conjunctivitis, with or without respiratory symptoms	Nasopharyngeal, combined oropharyngeal/nasal, and conjunctival swabs

Specimens should be sent to Missouri State Public Health Laboratory after approval by local public health authority

Source: https://www.cdc.gov/bird-flu/prevention/hpai-interim-recommendations.html accessed 5/12/26

requested to change clothing at the beginning and end of their shifts.[27] The Missouri Department of Agriculture offers detailed guidance for preventing HPAI H5N1 infections in poultry flocks and livestock herds.[45,46] Biocontainment measures entail cleaning and disinfecting clothing and boots worn around sick cows before working with other cattle and geographically separating poultry, cattle, and other species [27, 46]

There are no licensed H5N1 vaccines for cattle. The USDA has partnered with states, milk processing plants, and bulk milk transporters to establish the National Milk Testing Strategy (NMTS). Screening for H5N1 has been expanded to many dairy farms and to milk processing and transfer facilities.[47] Lactating cattle may move interstate if they originate from states in the NMTS Unaffected State Status category. State-specific guidance for moving cattle must be followed. Lactating cattle that show signs of infection such as lethargy or reduced milk production are ineligible for interstate transfer or movement to slaughter.

Vaccines

For decades influenza vaccine production has utilized an egg-based production method which requires up to six months and is now considered archaic.[48,49] The composition of seasonal influenza vaccines, which include two H types and one N type, is altered each year. The lag time between identification of circulating viral types and subtypes and annual vaccine release predictably leads to variable effectiveness due to frequent viral antigenic drift, short-lived immunity, and a lack of broad protection.[48,49,50]

Multiple H5N1 vaccines have been developed, most of which are egg-based and contain inactivated virus.[49] The three licensed H5N1 vaccines in the US were released in 2007, 2013, and 2020.[51] A national pre-pandemic stockpile, currently containing approximately five million doses, was established in 2005. [52] In 2024 stockpiled vaccine exhibited activity against the 2.3.4.4b subclade. [53]

There has been longstanding interest in developing next-generation influenza vaccines that could provide durable protection across diverse subtypes, reduce the likelihood of antigenic mismatches, replace slow egg-based production, generate robust immunity, and increase efficacy.[4,10,48,49,50] A universal influenza vaccine could evoke immune responses to conserved viral matrix proteins or nucleoproteins which are less prone to mutation than the H and N proteins targeted by current seasonal vaccines.[49] Other novel broadly protective vaccines also may be effective against multiple emerging subtypes.[48,50] More than a dozen candidates for universal or broadly protective vaccines are being studied in clinical trials, including mRNA vaccines which could enable a precise, rapid approach to new vaccine development, aimed at protecting the population from worrisome emerging variants.[4,49,50]

Pandemic Potential

Common features of novel viruses which have caused pandemics include viral avidity for α-2,6 sialic acid receptor binding sites in human respiratory tract epithelium, ability to disseminate outside the respiratory tract, high virulence, immunologic naivety in the population, and the capacity for efficient human-to-human transmission.[6,54] To date circulating H5N1 clades and subclades generally have not acquired these properties and have posed relatively low risks to humans.[10]

H5N1 binds to α-2,3 sialic acid receptors on the external surfaces of human conjunctival epithelial cells, a possible explanation for the high frequency of conjunctivitis in human H5N1 cases.[4,7,10,12,26] Alpha-2, 3 sialic acid receptors, although scarce in the human upper respiratory tract, are present in the lower respiratory tract. Thus, in acutely ill patients who have suspected H5N1 pneumonia, induced sputum, bronchoalveolar lavage fluid or endotracheal aspirate specimens should be submitted for H5N1 testing to increase diagnostic yield.[33,34]

There are multiple avenues for catastrophic reassortments or mutations which could create new mammalian-adapted, virulent pandemic H5N1 variants. In a person co-infected with both avian and human influenza viruses, reassortment of RNA could occur within a human cell, potentially leading to a new viral

lineage that is both contagious and virulent.[10] Similar mixing of viruses could take place in pigs, which historically have played the most important roles in introducing pandemic viruses, or in other mammalian species.[3,4] To date, sentinel contact pigs have been seronegative for H5N1 indicating that viral replication in these animals is ineffective.[55] Mutations enhancing contagiousness or virulence also could emerge during a prolonged human H5N1 infection.[29]

In addition to H5N1, other circulating H and N types carry potential pandemic risks. Through reassortment events in subclade 2.3.4.4, H5 acquired different neuraminidases resulting in the evolution and spread of H5N2, H5N5, H5N6, and H5N8.[1,5] In late 2025 the first human case of H5N5, which was fatal, was reported in Washington state.[56] Of concern, the robust human-avian interface at many live bird markets offers multiple opportunities for cross-species spillover of other influenza subtypes.[56]

The bottom line: no one knows when we will be beset by the inevitable future influenza pandemic, or whether it will be caused by a new H5N1 variant or by novel H and N subtypes. The maxim that "we should expect the unexpected" is apt.

Conclusions

The current epizootic of HPAI H5N1 in wild birds, the ongoing lethal poultry outbreaks in Missouri and elsewhere, the recent spread to cattle and other mammals, and the certainty of continued viral evolution that will carry the potential for eventually conferring human-to-human transmissibility and increased virulence, all raise substantial concern about H5N1 pandemic potential. Future universal or broadly protective vaccines offer promise for enhancing our ability to control emerging influenza variants. Close collaboration among health care workers, local public health agency personnel, and the agricultural and veterinary communities is necessary to limit potentially devastating spread of H5N1.

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Breast Cancer Awareness and Screening Barriers Among Women in a Diverse Urban Setting

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This study aims to contribute to the discourse on improving breast cancer outcomes for women in underserved communities.



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Abstract

Breast cancer remains a leading cause of morbidity and mortality among women. Early detection through mammography is crucial for improving survival. Despite widespread awareness, disparities in screening persist. This cross-sectional survey examined perceptions and barriers to mammography among 117 women aged 40–75 receiving primary care services in an urban, academic medical center in Kansas City, Missouri. Most participants reported awareness of breast cancer risks, recognized the importance of mammography, and had undergone at least one screening. However, 61% reported skipping, delaying, or avoiding mammograms. Commonly cited barriers included lack of physician referral, distance to screening sites, work conflicts, and transportation challenges. Younger women and those with lower household incomes were more likely to forgo screening. Findings underscore that knowledge and provider recommendations alone are insufficient; structural and emotional barriers must also be addressed. Targeted interventions, including patient navigation, mobile screening, and culturally tailored counseling, are needed to improve adherence.

Key Words

Breast cancer, risks, awareness, mammorgrams, underserved communities, barriers.

Introduction

Breast cancer remains the most commonly diagnosed cancer among women worldwide and continues to present a major public health challenge in the United States (US). According to the American Cancer Society,[1] breast cancer accounts for approximately 30% of new cancer cases in women annually. Despite advances in treatment, early detection through routine mammography remains the cornerstone of reducing mortality.[2] National guidelines from organizations such as the US Preventive Services Task Force recommend that women aged 40 and older undergo mammography

screening every one to two years to facilitate early diagnosis and improve survival rates.[3]

However, despite clear evidence supporting the benefits of screening, substantial disparities persist in mammography uptake, particularly among socioeconomically disadvantaged women, racial and ethnic minorities, and those with limited access to healthcare services.[4,5] These disparities contribute to later-stage diagnoses and poorer breast cancer outcomes in these populations.[6] Understanding the factors influencing screening adherence is, therefore, critical to reducing inequities in breast cancer outcomes.

While structural barriers, such as lack of insurance, transportation challenges, and limited clinic availability, are well recognized,[7,8] less attention has been paid to individual-level knowledge gaps, perceptions, and emotional factors that may hinder screening behaviors.[9,10] Research indicates that women's beliefs about breast cancer risk, trust in mammography, and experiences with healthcare providers significantly shape their screening decisions.[9,10] Misconceptions about breast cancer being rare or mammograms being unnecessary without symptoms persist, especially among young women.[11,12]

Emotional barriers including fear of results, embarrassment during the procedure, and anxiety about the possibility of a cancer diagnosis further compound these challenges and reduce screening adherence.[13,14] Moreover, sociodemographic factors such as younger age within the screening group, lower income, and less educational attainment have consistently been associated with low mammography rates.[2]

Designing effective interventions to increase breast cancer screening uptake begins with a clear understanding of women's current knowledge, perceptions, and the practical barriers they encounter. This study addressed this need through a survey of a diverse group of women aged 40 and older in Kansas City, Missouri, to identify key facilitators and obstacles to mammography. Community-specific surveys like this provide valuable insights into the nuanced reasons why some women underuse screening services. Capturing women's self-reported experiences and attitudes helps ensure the findings generate actionable strategies that address both educational gaps and systemic obstacles. Ultimately, this study aims to contribute to the discourse on improving breast cancer outcomes for women in underserved communities.

Methodology

Study Design

This study employed a cross-sectional descriptive survey design to assess breast cancer knowledge, perceptions, and barriers among adult women eligible for routine mammography screening.

Setting, Population, Sampling, and Data

Collection Procedures

The study protocol was approved by the Institutional Review Board at the University of Missouri-Kansas City. The research was conducted at an Internal Medicine primary care clinic within the University Health system in Kansas City, Missouri. The target population comprised adult women aged 40 to 75 years attending scheduled primary care visits, aligning with national screening guidelines from the US Preventive Services Task Force, which recommend routine mammography every one to two years starting at age 40. Eligible participants were biologically female, at least 40 years old, and able to read and complete a survey in English.

A convenience sampling strategy was employed, recruiting voluntary participants during routine clinic visits. Recruitment materials, including a flyer approved by University Health Public Relations, were displayed in exam rooms and waiting areas. The flyer outlined eligibility criteria and included a QR code linking to the electronic survey. Student investigators encouraged medical students and clinical staff to draw patients' attention to the flyer but did not engage in direct recruitment beyond this measure. All eligible individuals received written information detailing the study's purpose and scope and provided informed consent prior to survey completion. Participation was voluntary and responses were collected anonymously.

Following consent, participants independently completed the survey while awaiting or concluding their clinic appointments. Paper surveys were available upon request for individuals unable to access the electronic version. Flyers remained posted until the target sample size was attained. The final sample consisted of patients receiving primary care services at University Health between May 2023 and January 2025.

Survey Instrument

Data were collected using a structured, self-developed questionnaire. The instrument included closed-ended questions with categorical response options (e.g., yes/no), Likert-scale items (e.g., agree/disagree), and a few open-ended prompts for additional comments. The survey comprised several sections, including:

- Demographics: Age, race/ethnicity, education level, household income, marital status, and insurance status.
- Screening Behavior: History of prior mammograms, frequency of screening, and reasons for screening or non-screening.
- Perceived Barriers: Practical barriers such as transportation, cost, scheduling conflicts, and child or elder care responsibilities.
- Knowledge and Perceptions: Awareness of breast cancer risks, early detection benefits, and trust in mammography.
- Health System Factors: Whether a healthcare provider had recommended a mammogram in the past 12 months.

Data Handling and Analysis

All survey responses were captured using REDCap. Paper surveys were securely transferred and manually entered into the system by student investigators. The data were subsequently exported from REDCap into SPSS version 30 for analysis. Descriptive statistics, including frequencies and percentages, were calculated to summarize participant demographics and responses related to knowledge, perceptions, and barriers. Chi-square tests were performed to assess associations between demographic characteristics and screening behaviors.

Results

The following section presents the results of the study, highlighting participant demographics, breast cancer screening knowledge, perceptions, and reported barriers. Key associations between demographic factors and screening behaviors are also explored.

Participant Demographics

A total of 117 participants completed the survey. More than half of the respondents were aged 60 years and older, slightly over one-third were in their fifties, and the smallest proportion were aged 40 to 49. The majority of participants identified as Black or African American, followed by those who identified as White or Caucasian, with smaller groups identifying as Asian, Hispanic or Latino, or American Indian/Alaska Native. In terms of education, about a third had some college education, while others reported holding a high school diploma or GED, having completed graduate school, or having some high school education. Most participants reported working full time, while others were retired, disabled, working part time, or unemployed. Household income levels varied, with many reporting lower income brackets and fewer participants reporting higher annual household incomes. Table 1 presents a detailed summary of the demographic characteristics of the sample.

Breast Cancer Information Acquisition

Most participants were familiar with breast cancer and did not perceive it as a rare condition, with the majority also reporting that they knew a friend or family member who had been diagnosed. Consistent with this awareness, most agreed that mammograms are an effective method for detection. Information about breast cancer screening had been received by more than half of respondents through their doctor's office, while many had also accessed information from other sources. Nearly all participants reported that a healthcare provider had advised them to get a mammogram, and most did not encounter difficulties scheduling an appointment. The majority of participants had undergone at least one mammogram in the past,

Table 1. Demographic Characteristics of Participants (N = 117)

Variable	*Category*	*Frequency (N)*	*Percent (%)*
Age	40–49 years	15	13%
	50–59 years	37	32%
	60+ years	65	56%
Race/Ethnicity	White or Caucasian	31	26%
	Black or African American	66	56%
	American Indian or Alaska Native	1	1%
	Asian	12	10%
	Hispanic, Latino, or Spanish	7	6%
Education	Some high school	15	13%
	High school diploma or GED	29	25%
	Some college	35	30%
	Bachelor's degree	16	14%
	Graduate school	20	17%
Employment Status	Working full time	47	41%
	Working part time	9	8%
	Disabled	24	21%
	Unemployed	8	7%
	Retired	27	24%
Annual Household Income	Less than $20,000	43	38%
	$20,000–$39,999	31	27%
	$40,000–$59,999	11	10%
	$60,000–$79,999	8	7%
	$80,000–$99,999	6	5%
	$100,000–$149,999	12	10%
	$150,000 or more	3	13%

Table 2. Breast Cancer Information Acquisition

Question	Yes N (%)	No N (%)	Not Sure N (%)
Have you ever heard of breast cancer?	95 (82)	21 (18)	N/A
Do you know a friend or family member diagnosed with breast cancer?	82 (70)	29 (25)	6 (5)
Do you think breast cancer is a rare disease?	11 (10)	90 (78)	15 (13)
Do you think mammograms can detect breast cancer?	104 (89)	6 (5)	7 (6)
Received breast cancer screening info from doctor's office?	94 (81)	13 (11)	9 (8)
Received breast cancer info from other than doctor's office?	66 (56)	46 (39)	5 (4)
Has a doctor ever told you to get a mammogram?	112 (97)	4 (3)	N/A
Ever had trouble getting an appointment for a mammogram?	5 (4)	111 (95)	1 (1)
Have you ever had a mammogram?	113 (97)	3 (3)	N/A
Have you ever skipped, delayed, or avoided getting a mammogram?	69 (61)	45 (39)	N/A

although nearly two-thirds reported that they had, at some point, skipped, delayed, or avoided screening. Table 2 presents these details.

Reasons for Not Getting Screened for Breast Cancer

We sought to understand why participants chose to skip, delay, or avoid mammography. Among the 66 participants (61%) who reported postponing or forgoing screening, the most commonly cited reasons were lack of awareness about the necessity of the test, not having a physician's referral, and distance to the screening site. Additional barriers frequently mentioned included work-related time constraints, fear of the results, and transportation challenges. Less commonly reported factors were concerns about radiation exposure, feelings of embarrassment, and language difficulties. Further details are presented in Table 3.

Demographic Differences in Receiving Information and Mammogram Adherence

We conducted Chi-square analyses to examine whether participants' responses differed significantly across key demographic groups. Statistically significant differences were identified for only two outcomes: receipt of breast cancer screening information from other than the doctor's office and

Table 3: Reasons for Not Getting Screened for Breast Cancer

Reason	*Frequency*	*Percentage (%)*
I did not know I needed the test	95	81.2
I did not have an order from my doctor	89	76.1
Distance to the test location	88	75.2
Work obligations	86	73.5
Fear of the results of the test	85	72.6
Transportation problems	83	70.9
I was worried about the cost of the exam	81	69.2
I did not think my insurance would pay for the test	79	67.5
I did not have insurance	73	62.4
I did not want to get the test	19	16.2
Embarrassment or discomfort with having to change into a gown	19	16.2
I was worried about radiation from the test	14	12.0
Language barrier	12	10.3
The test is painful	14	12.0
I do not like coming to the hospital or clinic	14	12.0

Table 4: Demographic Differences in Receiving Information and Mammogram Adherence

		Received breast cancer info from other than doctor's office			Skipped, delayed, or avoided getting a mammogram		
Demographic Variable	*Categories*	*(%)*	*χ^2 Stat.*	*p-value*	*(%)*	*χ^2 Stat.*	*p-value*
Age (years)	40–49	58	$\chi^2(2)=3.45$	0.178	42	$\chi^2(2)=6.12$	0.047*
	50–59	66			32		
	60+	72			24		
Education	Some high school	52	$\chi^2(4)=9.88$	0.042*	39	$\chi^2(4)=4.32$	0.363
	High school diploma	60			36		
	Some college	71			28		
	Bachelor's	74			27		
	Graduate school	78			23		
Employment Status	Working full time	74	$\chi^2(4)=8.77$	0.033*	25	$\chi^2(4)=3.15$	0.532
	Part time	70			31		
	Disabled	55			34		
	Unemployed	57			30		
	Retired	69			29		
Income	<$20,000	59	$\chi^2(2)=4.12$	0.128	41	$\chi^2(2)=7.92$	0.019*
	$20k–$39,999	67			32		
	$40k+	71			22		

**Denotes statistical significance at the 0.05 level*

the likelihood of skipping, delaying, or avoiding a mammogram. The following section, therefore, focuses on how these two outcomes varied by demographic characteristics. Other survey items were not examined further, as they did not demonstrate statistically significant variation or showed response patterns too skewed to warrant additional subgroup analyses.

Age was significantly associated with mammogram avoidance ($p = 0.047$), with younger women more likely than older women to report skipping, delaying, or avoiding the procedure. However, age was not significantly related to whether participants received screening information from sources outside of a doctor's office. Similarly, education level demonstrated a significant relationship with receipt of screening information ($p = 0.042$); women with higher educational attainment were more likely to report receiving information from sources other than a doctor's office. However, education level did not significantly influence the likelihood of skipping or delaying a mammogram.

Employment status also showed a significant association with receipt of information ($p = 0.033$). Respondents working full time were most likely to report receiving information from non-clinical

sources, while those who were unemployed or disabled reported the lowest rates of receiving information elsewhere. Employment status, however, did not show a significant relationship with mammogram avoidance. Finally, household income was significantly associated with the likelihood of skipping, delaying, or avoiding a mammogram ($p = 0.019$), with women in lower-income households more likely to report avoidance than those with higher incomes. Income did not significantly affect whether women received screening information from sources other than a doctor's office. These findings are summarized in Table 4.

Discussion

This study provides important insights into the breast cancer screening experiences, barriers, and demographic disparities among women aged 40 to 75 receiving primary care services within an urban health system. Overall, participants demonstrated substantial awareness of breast cancer and its risks. Nearly all respondents recognized the critical role of mammography in early detection, and the majority reported having undergone at least one screening. The high rates of provider engagement reported further support existing evidence that healthcare provider recommendations remain a key driver of adherence to mammography guidelines.[2,9]

Despite this high level of awareness, nearly two-thirds of participants reported having skipped, delayed, or avoided a mammogram at some point. This underscores that knowledge and provider recommendations alone are not always sufficient to ensure consistent screening adherence. The reasons offered for non-adherence reveal a complex interplay of informational, structural, and psychosocial barriers that continue to impede timely screening. Commonly cited practical obstacles included not having a physician's order, long distances to screening facilities, transportation difficulties, and work-related conflicts. These barriers are well documented in the literature as persistent challenges for many women.[4,8] Additionally, emotional factors such as fear of receiving unfavorable results and feelings of embarrassment further contributed to avoidance, reinforcing the importance of patient-centered communication and culturally responsive support to address these concerns.[13,14]

Notably, this study identified clear demographic differences in both the receipt of screening information and adherence to recommended mammography. Younger women were significantly more likely than older participants to report skipping, delaying, or avoiding mammograms. This is consistent with Mafuvadze et al.,[11] whose study underscored early gaps in breast cancer knowledge among younger populations and recommended that educational interventions begin early and continue throughout adulthood to build and reinforce awareness. Income-related disparities were also evident, with women in lower-income households more likely to forgo screening altogether. This finding aligns with extensive evidence demonstrating how economic constraints and related structural barriers continue to limit access to preventive health services.[4,5,8] These patterns underscore calls in the literature for targeted interventions that address cost, transportation, and other social determinants of health to improve screening uptake among economically disadvantaged groups.[7,10]

While education and employment status were significantly associated with where participants received breast cancer information, they did not directly predict screening adherence in this sample. This finding indicates that simply providing information, whether through healthcare providers or other community channels, may not translate into action if practical and psychological barriers remain unaddressed.[11,10]

Taken together, these findings highlight the multifaceted nature of mammography adherence and the necessity of multi-level interventions. Building on work by Williams et al.[7] and Patel et al.[8] this study reinforces that successful screening promotion strategies must combine education with robust structural supports. Mobile

mammography units, transportation assistance, and patient navigation services can directly mitigate logistical obstacles, while tailored counseling can help address fear, stigma, and other emotional barriers to care.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, reliance on self-reported data may introduce recall or social desirability bias, potentially affecting the accuracy of participants' responses regarding mammography adherence. Second, data were collected from a single urban healthcare system in Kansas City, which may limit the generalizability of the findings to other regions, rural settings, or healthcare systems with different patient populations. Third, the cross-sectional design captures experiences and barriers at a single point in time, preventing assessment of changes in screening behaviors over time. Finally, while the study included a diverse sample, some subgroups may have been underrepresented, which could influence the applicability of the findings to all women aged 40 and older.

Conclusion

Despite these limitations, this study provides meaningful insights into the multifaceted barriers and facilitators of mammography adherence. The findings highlight the importance of sustained, early, and community-engaged outreach efforts, particularly for younger women who may underestimate their personal risk and for those in lower-income households who face multiple structural barriers to care. Partnering with trusted community organizations, employing multimedia communication strategies, and delivering culturally tailored education represent promising approaches to increase screening participation and advance breast cancer prevention efforts in underserved communities.

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Rural Cardiovascular Health in Missouri: Needs, Care Gaps, and Resources for a More Connected System

by Adnan I. Qureshi, MD, Hatem Tolba, MD, Muhammad Shah Miran, MD, Muhammad Shakir, MD, & Camilo R. Gomez, MD

Missouri should use cardiovascular health as a test of rural transformation: can the state connect prevention, urgent treatment, recovery, and social support in the places where people live?



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Abstract

Missouri's rural health needs are inseparable from cardiovascular health. Nearly one-quarter of Missourians live in nonmetro areas, where rural hospitals, clinics, community health centers, emergency medical services agencies, public health departments, and community organizations anchor care. Yet heart disease is the leading cause of death in Missouri; the 20 counties with the highest heart disease death rates are rural; and recent data show higher rural heart disease and stroke mortality than urban Missouri. Cardiovascular risk is shaped by clinical care, primary care access, transportation, insurance, broadband, food security, medication affordability, and specialty referral networks. Missouri has building blocks: critical access hospitals, rural clinics, federally qualified health centers, the Misouri Time Critical Diagnosis System for ST-elevation myocardial infarction (STEMI) and stroke, heart disease and stroke prevention program, workforce recruitment programs, and rural health transformation initiatives. This article proposes a rural cardiovascular agenda centered on prevention, urgent treatment, recovery, and community-level coordination.

Keywords

Rural health, cardiovascular disease, stroke, hypertension, Missouri.

Introduction: Cardiovascular Disease as a Rural Health Lens

Rural health in Missouri is often described through workforce shortages, hospital finances, transportation barriers, and social need. Those issues are real, but they can become abstract unless anchored to conditions that patients and clinicians encounter daily. Cardiovascular disease provides that anchor. It is common, lethal, preventable, and highly sensitive to the design of local systems of care. A patient with uncontrolled hypertension, diabetes, tobacco exposure, atrial fibrillation, or angina may need primary care, medications, diagnostic testing, specialty consultation, transportation, healthy food, emergency medical

Table 1. Selected Missouri rural health and cardiovascular indicators

Domain	Selected Missouri indicator	Why it matters for cardiovascular health	References
Rural population	1,513,013 Missourians (24.4%) live in nonmetro areas.	Cardiovascular prevention and follow-up must work at rural scale, not only through metro referral centers.	1
Workforce access	344 primary care HPSA designations; 1,837,226 people in designated HPSAs; 21.5% of need met; 475 practitioners needed to remove designations.	Hypertension, diabetes, tobacco cessation, atrial fibrillation, lipid therapy, and medication management depend on stable primary care access.	4
Behavioral health access	263 mental health HPSA designations; 1,928,387 people in designated HPSAs; 15.18% of need met.	Depression, substance use, stress, and social isolation affect adherence, cardiac recovery, and risk-factor control.	12
Heart disease mortality	Heart disease is Missouri's leading cause of death; the 20 counties with the highest heart disease death rates are rural.	The rural cardiovascular burden is not marginal; it is central to Missouri's mortality profile.	2
Rural/urban mortality	2019-2023 rural heart disease death rate: 218.5 per 100,000 vs. 182.6 urban; rural stroke death rate: 41.3 vs. 38.8 urban.	Emergency response, primary prevention, and post-event recovery need rural-specific design.	2
Broadband	20% of rural households lack an internet subscription compared with 12% of urban households.	Telecardiology, telestroke follow-up, remote blood-pressure monitoring, and patient education require broadband access and digital support.	2
Transportation and distance	Missouri's State Health Assessment describes transportation challenges and distance from services as barriers to healthcare access, especially in rural areas.	Missed visits, delayed treatment, and poor post-discharge follow-up undermine cardiovascular outcomes.	2

services, and follow-up after a hospitalization. In rural communities, each link in that chain is more fragile.

Missouri has a substantial rural footprint. Rural Health Information Hub reports that 1,513,013 Missourians, or 24.4% of the state population, live in nonmetro areas, and lists 35 critical access hospitals, one rural emergency hospital, 316 rural health clinics, 207 federally qualified health center sites, and 24 short-term/Prospective Payment System hospital (PPS) hospital sites outside census urban areas of 50,000 or more people.[1] Selected rural infrastructure and access indicators are summarized in Table 1. These assets are meaningful; they are also stretched. Cardiovascular health improvement therefore requires a strategy that supports rural clinical sites, reduces avoidable transfers, strengthens emergency medical services (EMS) and emergency pathways, and addresses the social drivers that determine whether patients can sustain treatment over time.

Missouri's Rural Cardiovascular Burden

The 2024 Missouri State Health Assessment identifies heart disease as the leading cause of death in both the United States (US) and Missouri and reports a 5.7% increase in Missouri heart disease death rates over the prior decade.[2] The same assessment notes that the 20 Missouri counties with the highest heart disease death rates are in rural regions of the state, with Pemiscot County having the highest rate during 2012-2021.[2] Disparities also cross race and sex: death rates due to heart disease were 24% higher for Black/African American residents than for white residents, and male rates were substantially higher than female rates.[2] These mortality indicators are included in Table 1.

A rural-specific view is even more sobering. The Missouri Office of Rural Health and Primary Care's 2024-2025 Health in Rural Missouri report shows that, for 2019-2023, heart disease was the leading cause of death statewide and in rural Missouri. The age-adjusted heart disease death rate was 218.5 per 100,000 in rural

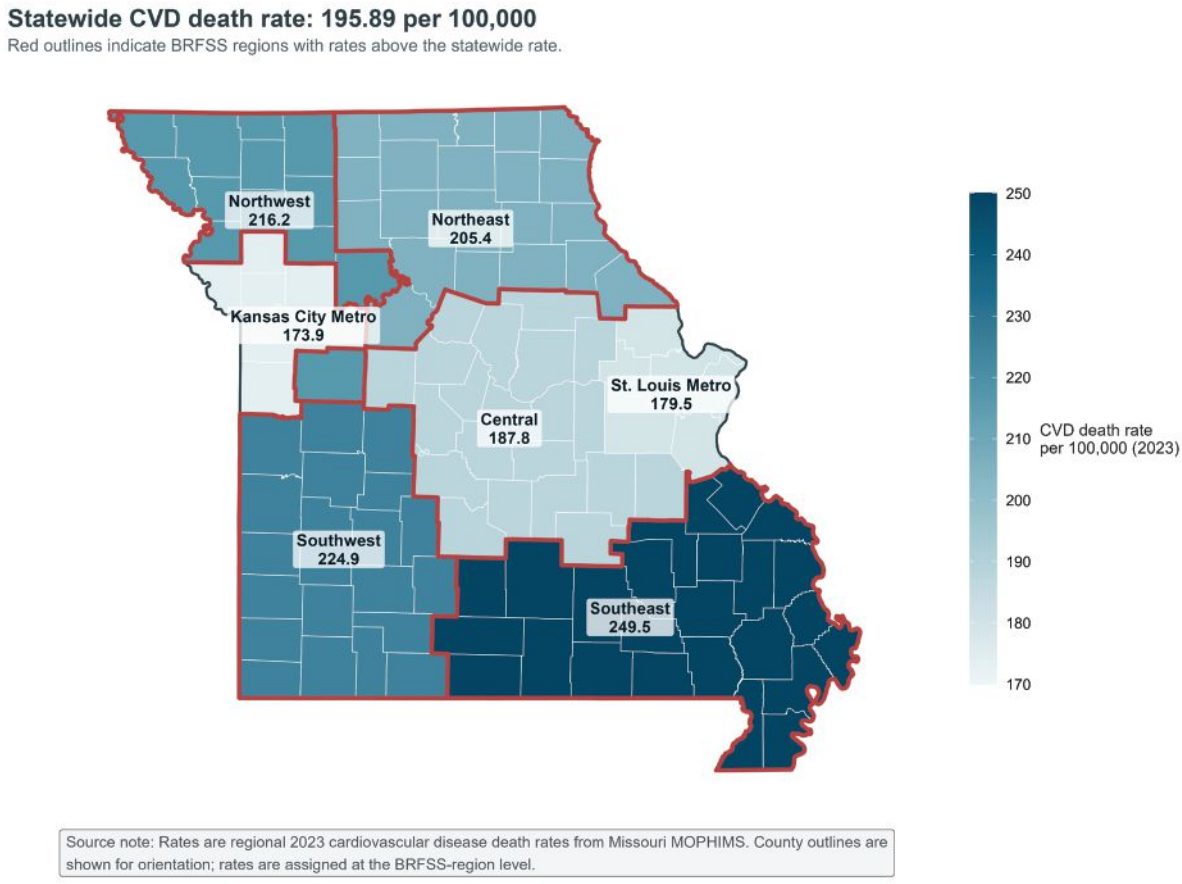


Figure 1: Cardiovascular mortality burden by Missouri Behavioral Risk Factor Surveillance System region. This figure presents 2023 cardiovascular disease death rates by Missouri Behavioral Risk Factor Surveillance System region, not county-level mortality. Rates were obtained from the Missouri Public Health Information Management System and are reported per 100,000 population. Regions above the Missouri statewide cardiovascular disease death rate of 195.89 per 100,000 are outlined in red. Regional rates were: Southeast, 249.52; Southwest, 224.91; Northwest, 216.19; Northeast, 205.41; Central, 187.76; St. Louis Metro, 179.48; and Kansas City Metro, 173.92 per 100,000. County outlines are shown for orientation only; rates are assigned at the Behavioral Risk Factor Surveillance System-region level.

Missouri compared with 182.6 per 100,000 in urban Missouri. Stroke was the sixth leading cause of rural death, with a rural age-adjusted death rate of 41.3 per 100,000 compared with 38.8 per 100,000 in urban Missouri.[1] The rural-urban mortality comparison is summarized in Table 1, and regional cardiovascular mortality patterns are shown in Figure 1.

These numbers should not be read as evidence that rural residents or rural clinicians are failing. They reflect the accumulation of distance, workforce shortages, limited specialty availability, transportation barriers, broadband gaps, poverty, food insecurity, and medication affordability challenges. A 2025 nationally representative *Journal of the American Medical Association* (JAMA) cardiology study found higher rural rates of hypertension, hyperlipidemia, obesity, diabetes, and coronary heart disease among adults; the rural-urban differences were largest among younger adults and were largely explained by social risk factors such as poverty, education, food insecurity, and home ownership.[3] Missouri's rural cardiovascular strategy should therefore be clinical and community-based at the same time.

Why Rural Cardiovascular Care Is Difficult to Deliver

Cardiovascular care looks deceptively simple on paper: measure blood pressure, lower LDL cholesterol,

stop smoking, treat diabetes, prescribe guideline-directed therapy, call 911 for stroke or myocardial infarction, and follow patients after discharge. The difficulty is that each step relies on a system. Rural patients may face few appointment slots, long travel distances, sparse specialty services, limited public transportation, out-of-pocket medication costs, and intermittent broadband. Rural clinicians may face small teams, limited after-hours coverage, and complex transfer logistics. Rural hospitals and clinics may face narrow margins while still being expected to provide emergency stabilization, chronic disease management, and community health functions.

Primary care shortage data illustrate the scale of the problem. As of December 31, 2025, KFF's State Health Facts reported 344 primary care health professional shortage area designations in Missouri, with more than 1.8 million people in designated areas and only 21.5% of need met.[4] Cardiovascular care is particularly sensitive to these shortages because prevention depends on repeated, low-intensity interactions over years. A single specialist visit does not control population blood pressure. A single discharge summary does not guarantee medication access. A rural cardiovascular plan must make the routine work of care, follow-up calls, home blood-pressure readings, medication reconciliation, transportation support, nutrition counseling, and referral tracking, visible and funded.

The State Health Assessment also underscores the importance of broadband and transportation. High-speed internet allows access to health information, telehealth services, and care coordination, yet 20% of rural households in Missouri lack an internet subscription compared with 12% of urban households.[2] Listening-session participants also identified transportation and distance to services as barriers to healthcare access.[2] These are cardiovascular barriers: they determine whether a patient receives anticoagulation monitoring, heart-failure follow-up, lipid therapy, a sleep study, cardiac rehabilitation, or timely evaluation of transient neurologic symptoms.

Current Missouri Resources

Missouri is not starting from zero. The state has a rural healthcare infrastructure, public health programs, emergency-care systems, and a new transformation framework that can be aligned around cardiovascular goals. The central question is whether these resources can be connected into a coherent pathway for prevention, acute response, recovery, and long-term risk reduction. Current Missouri resources relevant to rural cardiovascular health are summarized in Table 2.

Rural Clinical Infrastructure

The Missouri Office of Rural Health and Primary Care serves as the State Office of Rural Health and supports rural access through community-based systems, recruitment, loan repayment programs, and information on rural health clinics.[1] Rural Health Information Hub lists 35 critical access hospitals, one rural emergency hospital, 316 rural health clinics, 207 federally qualified health center sites, and 24 short-term/PPS hospital sites outside large Census urban areas.[1] These facilities are the natural anchors for blood-pressure control, diabetes care, tobacco treatment, medication reconciliation, and local follow-up after myocardial infarction, stroke, heart failure, or peripheral vascular disease. These rural clinical assets are summarized in Table 2.

Federally qualified health centers and community health centers are also essential. The Missouri Primary Care Association describes Missouri community health centers as nonprofit, community-driven providers serving low-income and medically underserved communities and providing affordable primary and preventive services; many also offer dental, pharmacy, mental health, and substance-use services.[5] This scope matters because cardiovascular health is influenced by oral health, behavioral health, pharmacy access, and substance-use treatment as well as by office-based primary care. Their cardiovascular applications are included in Table 2.

Time Critical Diagnosis System for STEMI and Stroke

For acute cardiovascular events, Missouri's Time Critical Diagnosis (TCD) system is one of the state's most important assets. Missouri's Department of Health and Senior Services (DHSS) describes TCD as a system created to address

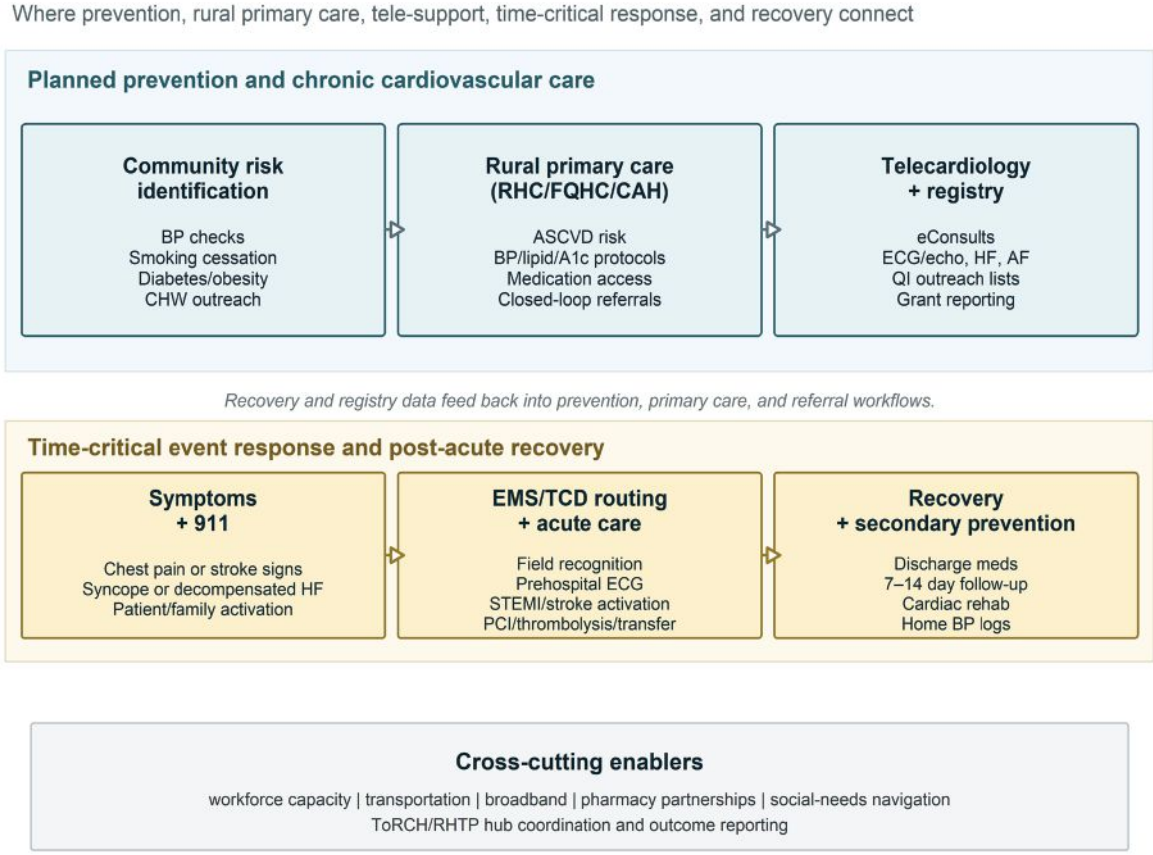


Figure 2. Rural cardiovascular care continuum in Missouri. This figure illustrates how rural cardiovascular care can connect planned prevention, rural primary care, telecardiology support, time-critical emergency response, post-acute recovery, and secondary prevention. The upper pathway emphasizes community risk identification, rural primary care through rural health clinics, federally qualified health centers, and critical access hospitals, and telecardiology or registry-supported care. The lower pathway shows emergency recognition, 911 activation, emergency medical services and Time Critical Diagnosis routing, acute care, and recovery planning. Cross-cutting enablers include workforce capacity, transportation, broadband, pharmacy partnerships, social-needs navigation, Transformation of Rural Community Health Care, Rural Health Transformation Program hub coordination, and outcome reporting.

preventable causes of death where "minutes matter," including trauma, stroke, and ST-elevation myocardial infarction (STEMI). The system coordinates transition from prehospital response to designated hospitals verified to have the resources, capability, and capacity for appropriate care.[6] For rural communities, TCD is not just a map of receiving hospitals; it is a framework for EMS protocols, transfer relationships, public education, and timely decision-making. The cardiovascular role of this system is summarized in Table 2.

TCD should be paired with longitudinal care. A rural patient who receives rapid reperfusion for STEMI or acute stroke treatment still needs medication access, follow-up appointments, risk-factor management, rehabilitation, transportation, and family education. The next generation of rural cardiovascular systems should link TCD discharge pathways with rural clinics, pharmacists, community health workers, cardiac rehabilitation options, home blood-pressure monitoring, and social-service referrals. This proposed care continuum is shown in Figure 2.

Prevention, Hypertension, and Public Health Programs

The Missouri Heart Disease and Stroke Prevention Program is housed within the Missouri DHSS Bureau of Cancer and Chronic Disease

Table 2. Current Missouri resources relevant to rural cardiovascular health.

Resource	Current role or status	Cardiovascular application
Critical access hospitals and rural emergency hospital	RHIhub lists 35 critical access hospitals and one rural emergency hospital in Missouri.	Emergency stabilization, local diagnostics, transfer coordination, heart-failure care, post-event follow-up partnerships.
Rural health clinics	RHIhub lists 316 rural health clinics in Missouri.	Team-based primary care, hypertension and diabetes registries, tobacco treatment, medication reconciliation, home BP monitoring.
Federally qualified health centers / community health centers	RHIhub lists 207 FQHC sites outside large urban areas; MPCA describes FQHCs as community-driven providers serving low-income and medically underserved communities.	Integrated primary care, behavioral health, pharmacy, dental care, SUD treatment, and preventive services.
Time Critical Diagnosis system	Missouri TCD coordinates trauma, stroke, and STEMI response through designated hospitals and prehospital-to-hospital pathways.	Faster STEMI and stroke treatment, EMS protocols, public education, and transfer relationships.
DHSS Heart Disease and Stroke Prevention Program	DHSS provides self-measured blood pressure, sodium reduction, Million Hearts, CDC, AHA, and WISEWOMAN resources.	Blood pressure control, risk-factor education, clinic workflows, patient-facing prevention tools.
Workforce programs	DHSS administers health professional loan and loan repayment programs and links to NHSC, HPSA, J-1, and 3RNet resources.	Recruitment and retention for primary care, behavioral health, pharmacy, and rural team-based care.
ToRCH Care / Rural Health Transformation	Statewide rural transformation strategy using local Hubs, Hub Anchors, care coordination, community health workers, referral systems, and partnerships.	A platform to align cardiovascular metrics with community referrals, EMS, clinics, pharmacies, hospitals, and social services.

3RNet, National Rural Recruitment and Retention Network; AHA, American Heart Association; BP, blood pressure; CDC, Centers for Disease Control and Prevention; DHSS, Department of Health and Senior Services; EMS, emergency medical services; FQHC, federally qualified health center; HPSA, health professional shortage area; MPCA, Missouri Primary Care Association; NHSC, National Health Service Corps; RHIhub, Rural Health Information Hub; STEMI, ST-elevation myocardial infarction; SUD, substance-use disorder; TCD, Time Critical Diagnosis; ToRCH, Transformation of Rural Community Health Care; WISEWOMAN, Well-Integrated Screening and Evaluation for Women Across the Nation.

Control. DHSS's heart disease and high blood pressure page highlights sodium reduction, self-measured blood pressure resources, the American Medical Association's SMBP (Self-Measured Blood Pressure) materials, Million Hearts hypertension protocols, American Heart Association resources, Centers for Disease Control and Prevention (CDC) resources, and Well-Integrated Screening and Evaluation for Women Across the Nation (WISEWOMAN).[7] These tools can support rural practices if they are operationalized through team-based workflows: validated blood-pressure devices, staff training, patient registries, standing medication protocols where appropriate, pharmacist collaboration, and feedback reports by clinic and county. These prevention resources are summarized in Table 2.

Workforce and Recruitment Resources

Workforce programs are part of cardiovascular prevention because clinician availability determines whether chronic disease is treated early. DHSS administers the Health Professional Loan Repayment Program and Student Loan Repayment Program options designed to increase access to care in Health Professional Shortage Areas (HPSA), and the same site links to recruitment resources, HPSA information,

the National Health Service Corps, J-1 Visa Waiver information, and 3RNet healthcare jobs.[8] These mechanisms should be used deliberately to place primary care clinicians, behavioral health clinicians, pharmacists, nurses, community health workers, and other team members in communities with high heart disease and stroke burden. Workforce-related resources are summarized in Table 2.

Transformation Of Rural Community Health (Torch) Care and Rural Transformation

Missouri's Transformation of Rural Community Health (ToRCH) Care initiative may become the most important organizing mechanism for rural cardiovascular improvement. Missouri Department of Social Services (DSS) describes the federal Rural Health Transformation Program as a five-year, $50 billion national investment and states that MO HealthNet is leading Missouri's application effort in collaboration with DHSS and the Department of Mental Health.[9] DSS has described ToRCH Care Hubs as local community networks organized around approximately three to five counties; partners may include hospitals, clinics, pharmacies, EMS, and community-based organizations, with Hub Anchors coordinating governance, care workflows, program staff, and community health workers.[9]

In April 2026, Missouri DSS announced Centers for Medicare and Medicaid (CMS) approval of $216 million in Year 1 funding through September 30, 2027, launching full implementation of ToRCH Care as Missouri's statewide transformation strategy.[10] A subsequent May 2026 DSS stakeholder update announced ToRCH Care Roadshows intended to connect directly with rural communities and help shape the future of rural health in Missouri; the same communication noted a CMS/HHS award of $216,276,817.66 supporting the Rural Health Transformation Program information provided by DSS.[11] Cardiovascular health should be a visible priority in this work because it is measurable, high-burden, and responsive to both clinical and social interventions. The cardiovascular application of ToRCH Care is summarized in Table 2.

A Cardiovascular Agenda for Rural Missouri

Missouri's rural transformation agenda should treat cardiovascular health as a core measure of whether rural systems are working. The following priorities are designed for physicians, clinics, hospitals, EMS leaders, local public health agencies, payers, and ToRCH Care Hubs.

1. Make Blood-Pressure Control the Statewide Rural "Vital Sign."

Hypertension is the most actionable cardiovascular risk factor. Every rural primary care site should be able to identify patients with uncontrolled blood pressure, confirm accurate measurement, provide validated home blood-pressure monitoring, adjust therapy rapidly, and track control rates. ToRCH Care Hubs could help clinics obtain devices, train staff, and connect patients with transportation, medication, food, and broadband support.

2. Link Emergency Care to Recovery and Prevention

The Time Critical Diagnosis (TCD) system addresses the front end of STEMI and stroke care. Rural improvement should now extend that system beyond the emergency event. Each STEMI, stroke, or heart-failure hospitalization should trigger a rural follow-up plan that includes a local appointment within seven to 14 days when clinically appropriate, medication reconciliation, transportation planning, rehabilitation options, home monitoring, tobacco cessation, and referral to community support.

3. Use Team-Based Care Where Specialty Access is Limited

Rural cardiovascular care cannot depend solely on cardiologists or neurologists. Primary care physicians, advanced practice clinicians, nurses, pharmacists, EMS clinicians, dietitians, behavioral health clinicians, and community health workers should operate from shared protocols. Standing workflows for hypertension, diabetes, LDL cholesterol, atrial fibrillation, heart failure, tobacco cessation, and post-stroke follow-up can make high-quality care less dependent on individual heroics.

4. Build Telehealth that Strengthens, Rather Than Replaces, Local Care

Telecardiology, telestroke follow-up, remote patient monitoring, and virtual cardiac rehabilitation can reduce travel burden, but they require broadband, devices, technical support, and local clinical ownership. The rural clinic should remain the patient's medical home; the technology should extend that home rather than fragment it.

5. Fund the Social Work of Cardiovascular Prevention

The social work of cardiovascular prevention is often unpaid but essential: arranging transportation, helping patients obtain medications, addressing food insecurity, locating blood-pressure cuffs, coordinating benefits, and following up after missed visits. The ToRCH Care model is well suited to make this work visible through community health workers, referral systems, and Hub-level accountability.

6. Measure What Matters Locally

Recommended rural cardiovascular metrics include blood-pressure control, LDL cholesterol control after atherosclerotic cardiovascular disease, tobacco cessation treatment, diabetes control, statin use for eligible patients, anticoagulation for atrial fibrillation where indicated, STEMI and stroke transfer times, seven- and 14-day post-discharge follow-up, cardiac rehabilitation participation or referral completion, medication access, and patient-reported transportation barriers. Metrics should be stratified by county, rurality, race/ethnicity, sex, insurance status, and age when feasible.

Role of Physicians and Physician Organizations

Missouri physicians can make rural cardiovascular health a practical agenda rather than a slogan. Primary care physicians can build registries and protocols; cardiologists and neurologists can design telehealth relationships with rural sites; emergency physicians and EMS medical directors can strengthen TCD pathways; public health physicians can align data and prevention efforts; and physician organizations can advocate for payment models that support team-based care, home monitoring, care coordination, and transportation solutions.

The most important leadership role may be convening. Many rural communities already have hospitals, clinics, pharmacies, EMS, local public health agencies, schools, churches, food banks, aging services, and community-based organizations doing pieces of the work. Cardiovascular outcomes will improve when those pieces become a system.

Conclusion

Missouri's rural cardiovascular needs are urgent but actionable. Heart disease is the state's leading cause of death, and the burden is concentrated in rural counties and communities facing workforce, transportation, broadband, and social-resource constraints. At the same time, Missouri has a strong foundation: rural hospitals and clinics, FQHCs, EMS, TCD-designated care, DHSS prevention programs, workforce programs, and the emerging ToRCH Care/Rural Health Transformation infrastructure. The next step is integration. Missouri should use cardiovascular health as a test of rural transformation: can the state connect prevention, urgent treatment, recovery, and social support in the places where people live? If it can, rural cardiovascular improvement will become not only a clinical success but also a model for rural health system redesign.

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11 days after appendectomy, tests for acute abdominal pain revealed a

retained object

left inside the patient.

Surgical miscounts are considered *never events* because they are usually preventable by following established procedures.

ProAssurance offers risk assessments designed to help practices minimize errors by establishing and evaluating safety procedures and communication protocols.

With reliable procedures in place, our insureds are more likely to reduce errors in their medical practice, avoid claims, and make claims more defensible if they do occur.

MALPRACTICE CLAIM CASE STUDY
Surgical Never Event: Retained Lap Pad

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