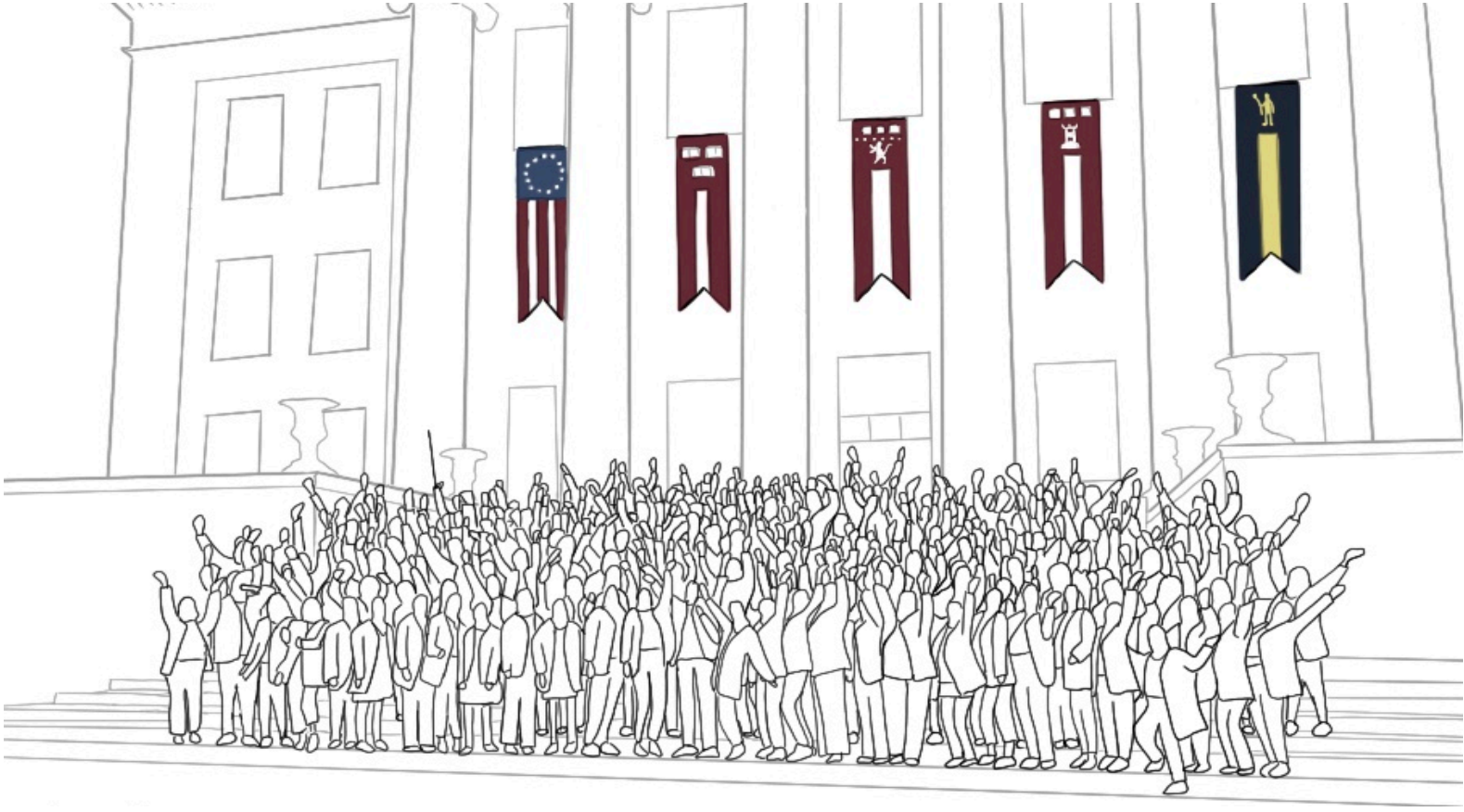


A Wishlist for the Future of Medicine

A Special Issue curated by the Harvard Medical Student Review

HMSR

December 25, 2025

Foreword by Dr. Jeremy S. Faust

This year, science, medicine, and academia faced an unprecedented reckoning. In light of this, we called on Harvard medical students to help illuminate the way forward, asking:

If we could wish for an ideal future of medicine, what would we ask for?

This collection is our answer.

About HMSR

The Harvard Medical Student Review (HMSR) is student-founded, student-led, and student-administered under the guidance of faculty and staff from Harvard Medical School and peer institutions., Its mission is to provide a platform for students to contribute to important issues facing health and medicine through a variety of formas, including scholarly articles, editorials, and original artwork. For this Special Issue, contributions were invited from Harvard medical students.

Letter from the Editor-in-Chief

The Next 25 Years: Harvard Medical Students' Wishes for the Future of Medicine

Arya S. Rao
Harvard Medical School Class of 2030

Amidst the past year's assaults on science, medicine, and academia at large, we at the Harvard Medical Student Review recognize that our profession stands at a precipice. The authority previously granted to clinical and scientific institutions is undergoing a profound interrogation. Skepticism regarding expertise has intensified, and the frameworks that govern healthcare delivery face significant political and economic pressure. In such a climate, the instinct to retreat into the insularity of the clinic or the laboratory is powerful.

However, we believe that the most powerful response to skepticism is not defensiveness—it is imagination. **In times of crisis, we are called upon not just to endure, but to innovate.** It is precisely when the status quo is most fragile that the imperative to chart a new course becomes most urgent.

To capture this spirit, we issued a Call for Submissions to the Harvard Medical School student body with an aspirational prompt: ***What is your wish for the next 25 years of medicine?*** The resulting perspectives are filled with a profound sense of hope and possibility.

A central tenet of this issue is the urgent need to **rebuild the social contract between medicine and the public**. Our contributors emphasize that the medical community must actively modernize its communication, reclaiming ground on the digital platforms where misinformation often takes root. They assert that the future of medicine depends on our ability to pair scientific advancement with radical ethical transparency.

We also share a fervent hope for a future of medicine that provides **sanctuary for all.** Our authors articulate a vision wherein equity is treated as a rigorous standard of practice, and where the physician's responsibility extends to any arena where patient well-being is at stake. They argue that representation in the workforce is essential to the healing process and that the role of the healer must expand to include the role of the protector—standing firm against legislative attempts to limit access to essential services, such as gender-affirming care.

Finally, we see a future where **the promise of the latest science—from gene therapy to tissue engineering—is accessible to all.** We envision a healthcare system that learns as it acts, utilizing universal data and artificial intelligence to sharpen our insights in real time. And to guide us through this era of exponential growth, our peers call for an education grounded in first principles, fostering a generation of physicians who understand the body deeply enough to welcome these innovations with confidence.

These essays serve as a reminder that medicine is, at its heart, an optimistic profession. We study, we practice, and we research because we believe that tomorrow can be better than today. This issue is our promise to help make it so.

Sincerely,

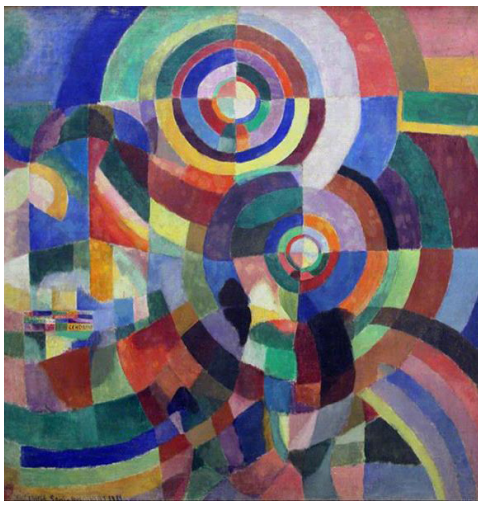
Arya S. Rao

Editor-in-Chief, *Harvard Medical Student Review*

Correspondence: arya_rao@hms.harvard.edu

Artwork: Sternennacht über der Rhône, 1888 by Vincent Van Gogh. Public domain. Courtesy of Wikimedia Commons.

TABLE OF CONTENTS



Foreword

Dr. Jeremy S. Faust

Assistant Professor, Harvard Medical School

Let us not train our future colleagues merely to replace us. Let us, instead, create the conditions that will enable them to redeem us. After reading the diverse essays in this volume, I believe you may share this thought—and join me in considering how we might achieve it.

As a profession and a discipline—if perhaps not as individuals—humility has always been medicine's greatest ally. Without it, change would not be possible. Yet, we relentlessly quiz our students to ascertain whether they have sufficiently incorporated into their memory banks what is. This has value and, whether we like it or not, is a necessity. But when was the last time you asked a student to "tell me something I'm wrong about"?

This brings to mind a familiar quotation, delivered to students by a past dean of this medical school's faculty, Dr. Charles Sidney Burwell: "Half of what we are going to teach you is wrong, and half of it is right. Our problem is that we don't know which half is which."

Readers often assume that Burwell was referring to disease mechanisms and treatments—and it is likely that in the middle of the 20th century, he indeed was. Today, that sentiment, repeated verbatim, remains correct. But I suspect its truth may now apply less to the *science of medicine* than to its *practice*. What good is knowing that new medications are somewhat superior to their predecessors when our systems are incapable of delivering them to populations most in need? We may now be teaching less of what is wrong, but still failing to teach what matters.

So, some good news: One thing we have recently done well, as a faculty, as a field, is to recruit students who, finally, are alert to this as a *primary concern*, rather than as an afterthought. However, having told them just how important this is, should they not be expected to observe that we have, as yet, failed to adequately achieve our values?

Fortunately *(perhaps uncomfortably for you and me)*, they have noticed, and they are growing impatient. This should not threaten but hearten us. There is nothing more powerful, nor worthy of our support, than students seeking to right

wrongs they encounter. Herein, you will find eight illuminating and fresh examples of that. Among the essays that follow, the number that could have (or likely would have) been written just 15 years ago is approximately zero.

Consider these notes from my readings of the essays contained in this volume.

- Most Americans can't name a living scientist. What can we do about that? How many lives will *that* save?
- Just how fragile is our commitment to workforce representation? What do we stand to lose if we quickly buckle under just a little bit of pressure?
- Can we change medicine's business model so that recent breakthroughs in preventive medicine are properly valued?
- Are we, by virtue of living and practicing *precisely here*, becoming too complacent? Are we as insulated from rapidly growing anti-scientific currents emanating from elsewhere as we wish to believe?
- What ceilings do we impose when we optimize for outcomes ("top-down") rather than processes ("bottom-up")?
- If we wish to save lives today, why are we focused on emerging technologies when the actions with the greatest potential to achieve this reside in something already well within grasp: restoring trust.
- Examinations—of which the various medical boards are the "final boss"—really do reveal what we value. How can we claim to embrace change when the requisite curricula and rite-of-passage ordeals reinforce the status quo, and even gatekeep against those who would seek to overturn it?
- When will we finally leverage our prodigious information technology effectively?

So, apparently, if you ask eight Harvard Medical Students to declare their wishes for the future of medicine over the next 25 years, you receive eight vastly different, but equally insightful answers—at least on the specifics.

But I could not help noticing that each essay landed upon a shared answer, a conserved residue, if you will: process over outcome. The students have, in a sense, articulated a medical and public health analog of the Miller–Urey experiments, in which four basic ingredients found on our planet's early environment (methane, water, ammonia, and hydrogen) spontaneously yielded amino acids when exposed to electricity.

When it comes to progress on the scientific front—the kind that we may well assume Dean Burwell was invoking—it's true that outcomes (patient-centered ones above all others) are what matter. But if we cling to outcome-orientation when reimagining our *field as a whole*, we may too easily fall prey to the forces of ideology. Yes, we'd like to believe that when "we" are in control, the right goals will be pursued, and that better and more righteous care will emerge. But what about when we are not in control? And what about those instances in which, perish the thought, we are wrong? If we heed the shared wish found in these essays and embrace the ethics of process-oriented approaches—that is, if we insist on a set of values in each and every of our endeavors—then, in time, **the results we hope to see will simply become *inevitable*.**

Correspondence: jsfaust@bwh.harvard.edu

Artwork: Electric Prisms, 1914 by Sonia Delauney. Public domain. Courtesy of WikiArt.

Facts Don't Care About Your Feelings: Reflections on Science Communication via Social Media

Anna Wadhwa
Harvard Medical School Class of 2030

Beyond doomscrolling and Tiktok micro-trends, what does social media have to offer us? Platforms have evolved significantly since SixDegrees was first created in 1997, to Friendster, MySpace, Facebook, nowadays Twitter, Instagram, and most recently Tiktok. Influencer culture on social media has simultaneously created both a treacherous arena of wellness culture grifters spewing misinformation, and a space for mindblowing creativity and talent to find dedicated fans (1). For scientists and physicians, it represents a powerful, but currently underutilized, tool for science communication and public outreach.

Scientific questions are often at the core of daily contentious topics: vaccine policies, gender-affirming care, social determinants of health, and more. **The public has a right to hear about these research findings first-hand from researchers themselves—not from @DrRandomUser whose credentials are a quick Google search or made-up certificate program.** How do we, as the scientists actually doing the science, study vaccine efficacy? How do we know gender-affirming care is beneficial for patients?

My recurring mantra for science communication on social media is "WDTDS: What does the data say?". This has been a powerful approach particularly when discussing the devastating cuts that funding cuts will have on American scientific innovation. It doesn't matter how you, I, or @DrRandomUser online feels about the science. Truthfully, it doesn't matter how any of us feel about the cuts—what matters is the data we will lose and the data that shows us how much we will lose (scientifically, economically, workforce numbers, etc.). At the end of the day, the data is what should be guiding our evidence-based medicine, public policy, and more.

I want us to use our platforms to show who we are.

Yet, science outreach must go beyond a simple presentation of the facts themselves. We must also demonstrate the hidden curriculum of the scientific approach: how to develop a healthy skepticism and how to understand the nuance inherent in all research. Not all research is good research, but how should a layperson go about determining that? We should be encouraging people to question scientific methods and disclosures of competing interests (yes, even when they question us too!). Why do we sometimes study autism spectrum disorder using rodent models instead of clinical trials? Should they listen to what @DrRandomUser is saying about their top 3 gut health hacks? Why or why not?

I hope that science communication not only teaches people about the science, but also about the scientists. I want us to use our platforms to show who we are. Who are the "entitled DEI hires" that are actually doing the work our Secretary of Health demands (2-4)? Who are the "whiny" students worried about their graduate school research funding (5)? What motivates us? Why do we do what we do? We know we are not evil overlords who profit off of illness and disease, but how can we show the public what actually fulfills us? I have found that a transparent approach on social media helps engage people in our journey and goals—no matter how big or small.

None of this is to say we are obligated to put our bad days on the internet for public viewing. Nor should this be considered a requirement to add on to the already overflowing to-do lists for many physicians and scientists. Many of us have no formal training in science communication or public outreach—and this is ok (6-7). But for those of us searching for a way to connect with the confused and the angry, with the skeptics and the believers, with the blue and the red, social media should not be overlooked as a tool for doing so.

Ultimately, I hope science communication in the future can take on a three-pronged message: teaching people about science, teaching people how to think about science, and teaching people who the scientists are. I believe continuous outreach in the face of anti-science skepticism will be critical for combatting the dangerous waves of misinformation crashing through our society. As social media continues to grow over the next 25 years, I hope more science communication will enable us to share our work, perspectives, and our stories with the public.

Don't forget to like, comment, subscribe for more.

References

1. Keikha L, Shahraki-Mohammadi A, Nabiolahi A. Strategies and prerequisites for combating health misinformation on social media: a systematic review. BMC Public Health. 2025 Dec 5; PMID: 41351160. Doi: 10.1186/s12889-025-25858-4

2. HHS Press Office. President Trump, Secretary Kennedy Announce Bold Actions to Tackle Autism Epidemic [Internet]. HHS.gov. 2025. Available from: https://www.hhs.gov/press-room/hhs-trump-kennedy-autism-initiatives-leucovorin-tylenol-research-2025.html

3. Iyer A. Understanding Advantaged groups' Opposition to diversity, equity, and Inclusion (DEI) policies: the Role of Perceived Threat. Social and Personality Psychology Compass [Internet]. 2022 Apr 13;16(5). Available from: https://compass.onlinelibrary.wiley.com/doi/full/10.1111/spc3.12666

4. Ahmed N. The Weaponization of DEI: Why Diversity Initiatives Are Under Fire - The Phoenix [Internet]. The Phoenix. 2025. Available from: https://swarthmorephoenix.com/2025/02/06/the-weaponization-of-dei-why-diversity-initiatives-are-under-fire/

5. Harvard Medical School to Cut 20 Percent of Research Spending, Dean Says in Annual Address. The Harvard Crimson. Thecrimson.com. 2024. Available from: https://www.thecrimson.com/

article/2025/9/18/hms-daley-state-of-the-school/

6. Fähnrich B, Wilkinson C, Weitkamp E, Heintz L, Ridgway A, Milani E. Rethinking Science Communication Education and Training: Towards a Competence Model for Science Communication. Frontiers in Communication. 2021 Dec 22;6. https://doi.org/10.3389/fcomm.2021.795198

7. Swords CM, Porter JS, Hawkins AB, Li E, Rowland-Goldsmith M, Koci MD, et al. Science Communication Training Imparts Confidence and Influences Public Engagement Activity. Journal of Microbiology & Biology Education. 2023 Aug 22;24(2). PMID: 37614888.

Correspondence: wadhwa@hms.harvard.edu

Artwork: The City, 1919 by Fernand Leger. Public domain. Courtesy of WikiArt.

From the Exception to the Norm: A Wish for More Latine Representation in Medicine

Sara Castro
Harvard Medical School Class of 2026

During a summer internship in a safety net hospital in California, the director of the hospital's catheterization lab became my assigned mentor. After weeks of shadowing during rounds, I had noticed that none of the students and trainees were Latine, besides me. "Why aren't there Latina residents or fellows?" I asked him point blank.

"Because they're stupid. In the 30-plus years I've been here, we've only interviewed two, and they were no good. It takes generations to become a physician." He gestured to the patients through the window, who were predominantly Latine. "Latinos immigrate to this country and don't even learn the language," he asserted.

All summer long, this physician – a leader in cardiology – referred to families like mine as "illegal aliens." Once he overheard me speaking to my father on the phone in Spanish. Years later, I can still remember his disapproving expression.

This mentor gave me a taste of the anti-immigrant and anti-diversity, equity, and inclusion (DEI) rhetoric we are all currently experiencing. As my medical school journey is coming to an end, I mourn the dissolution of

Harvard Medical School's Office of Recruitment and Multicultural Affairs and the accompanying significant decrease in funding for affinity groups (1). My mentor's words, long buried, resurface again as I see the number of admitted Latine medical students drop at Harvard. **How many generations of physicians will we lose because of these systemic changes?**

My wish for the future of medicine is that Latine physicians be fully represented within all medical fields, supported by their institutions, and empowered to provide culturally and language-concordant care. Achieving this requires structural reform in medical school admissions that acknowledges and corrects educational inequities. It also requires longitudinal institutional investment to counteract existing bias.

Today, policies against affirmative action and DEI threaten to dismantle the hard-earned progress of so many generations. The 2023 Supreme Court decision against affirmative action prevented medical schools from incorporating an applicants' race or ethnicity into the admissions decision, making it more difficult to create diverse classes (2). The impacts have been predictable, and we have seen this before. Economist Zachary Bleemer found that fewer students of marginalized backgrounds and identities applied to selective universities after California's affirmative action ban in the late 1990s (3). In 2025, only 6.8% of medical student applicants identified as Latine (4).

We are moving backwards in our fight towards a more diverse physician workforce.

Without tracking outcomes, we can't improve equity. This matters because even though Latines make up 20% of the U.S. population, we make up only 6% of the physician workforce (5). When my mentor said it took generations to become a physician, he was right in that household income and education are tightly linked. About 75% of medical students come from the top two household-income quintiles (6). First-generation, low-income (FGLI), medical students are underrepresented, systematically filtered out through the hidden curriculum and costly test strategy courses. Only 10.7% of the 2025-2026 medical school matriculants in the United States are first generation college graduates (7). To study medicine is a privilege very few can pursue, and FGLI Latine medical students are the exception, not the norm.

These numbers underscore what is at stake. **Without equitable policies, talented underrepresented students are at increased risk of exclusion.** What many don't realize is that increased representation benefits everyone and by having less diverse perspectives at the table, we all miss out – physicians, patients, medical students, our mentors and mentees. Research has repeatedly demonstrated that racial and language-concordant care improves patient outcomes (8). Who doesn't want better outcomes?

The work to improve equity should not end with acceptance letters; it must continue throughout training. Academic success in medicine often requires attending conferences to present research, away rotations, and third-party USMLE exam resources, all of which cost thousands of dollars. The system, once again, favors those who don't depend on institutional financial support to participate. Institutions are not built for those without access to the hidden medical curriculum.

Mentorship is one of the few existing tools to reduce this gap. Yet finding mentors and role models who share a background similar to mine is exceedingly rare. I cannot help but question the value of a mentorship relationship from someone who believes Latinas aren't intelligent. I share my personal narrative to illustrate the types of comments and biases we confront in medical settings and why I hope for a future in which finding race-concordant mentors is not the exception.

These challenges are not new. We carry the lessons from those who came before us. We have learned to over-rely on grit, resilience, and the

importance of taking care of our own. My hope is that FGLI Latine medical students are not performatively praised or tokenized for these traits but are genuinely valued for our merit and supported in ways that truly matter.

There will always be those who doubt our potential. But we get to choose who we listen to and how we show up. While we continue to advocate for institutional support, we must also find allies and create our own board of advisors. Our communities will continue to strengthen us if we build networks and bring our cultural values forward. When institutional support falls low, we, united in community, must rise. I was told it would take generations for someone like me to become a physician. Supported by family, friends, and believers, I clung to my dream, learned English, and this year will be graduating from medical school. It should not take another generation for Latines like me to be represented in the field. My goal is for stories like mine not to be the exception, but the norm.

References

1. Patel D. HMS restructures and renames diversity office, removes pledge to fight inequities [Internet]. The Harvard Crimson. 2025 [cited 2025 Dec 13]. Available from: https://www.thecrimson.com/article/2025/6/5/hms-dei-renaming/

2. Students for Fair Admissions, Inc. V. President and Fellows of Harvard College [Internet]. Supreme Court of the United States. 2023 Jun [cited 2025 Dec 13]. Report No.: 600 U. S. ____. Available from: https://www.supremecourt.gov/opinions/22pdf/20-1199_hgdj.pdf

3. Bleemer Z. Affirmative action, mismatch, and economic mobility after California's Proposition 209. The Quarterly Journal of Economics. 2022 Feb;137(1):115-60.

4. Table A-10: Applicants to U.S. MD-Granting Medical Schools by Race/Ethnicity (Alone) and State of Legal Residence, academic year 2025-2026 [Internet]. Association of American Medical Colleges; 2025 [cited 2025 Dec 13]. Available from: https://www.aamc.org/data-reports/students-residents/data/facts-applicants-and-matriculants

5. Corsino L, Chinea FM, Yee L, Fuller AT. Increasing Latinx representation in the US medical schools: A top-ranked medical school's experience. Frontiers in Public Health. 2022 Sep 16;10:907573.

6. Youngclaus J, Roskovensky L. An updated look at the economic diversity of U.S. medical students [Internet]. Association of American Medical Colleges; 2018 Oct [cited 2025 Dec 13]. Available from: https://www.aamc.org/media/9596/download

7. Table A-26: First generation applicants, acceptees, and matriculants to U.S. MD-Granting Medical Schools, academic years 2020-2021 through 2025-2026 [Internet]. Association of American Medical Colleges; 2025 [cited 2025 Dec 13]. Available from: https://www.aamc.org/data-reports/students-residents/data/facts-applicants-and-matriculants

8. Lopez Vera A, Thomas K, Trinh C, Nausheen F. A case study of the impact of language concordance on patient care, satisfaction, and comfort with sharing sensitive information during medical care. Journal of immigrant and minority health. 2023 Dec;25(6):1261-9.

Correspondence: saracastro@hms.harvard.edu

Artwork: Zapatista Landscape (The Guerilla), 1915 by Diego Rivera. Public domain. Courtesy of WikiArt.

Gene Therapy as Preventive Care: Rethinking Payment for One-Shot Cures

Arya S. Rao
Harvard Medical School Class of 2030

Gene therapy has revolutionized modern medicine, enabling transformative treatments for previously incurable diseases. As of 2023, 48 cellular and gene therapies are on the market, including Casgevy, the first FDA-approved CRISPR-Cas9 therapy. Hundreds more are currently in clinical development (1). Physicians will soon be able to wield these molecular scissors towards bespoke therapies for individual patients, promising personalized, one-shot cures for genetic diseases ranging from classic Mendelian disorders to complicated, heterogeneous cancers. Yet, current therapies average millions of dollars per dose, making treatment cost-prohibitive for patients (2).

As gene therapy begins its explosive rise, existing payment and delivery models are struggling to adapt. Medicaid programs are generally required to cover FDA-approved drugs, including gene therapies; however, given their high cost, they are typically subject to stringent prior authorization. Commercial insurance providers are not universally required to cover gene therapies, and current policies tend to restrict the number of patients who may receive gene therapy in a given year (3). Uninsured patients have little hope of meeting the high cost barrier.

Given the potentially curative benefits associated with a just single dose of gene therapy, cost

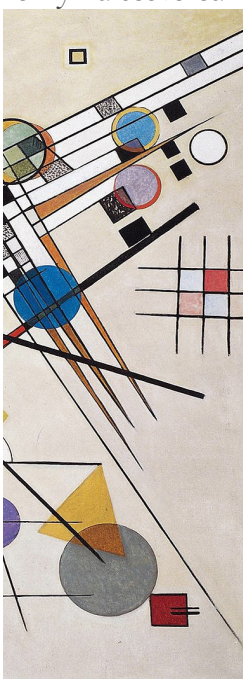
structuring for gene therapies must be adapted to maximally benefit patient wellbeing. The high upfront costs associated with gene therapies disincentivizes their use over traditional, long-term pharmacologic therapies which may offer temporary relief but do not address the root cause of disease. The healthcare system faces a serious challenge to evolve in response.

One novel approach to reimbursement is value-based care (VBC), in which payments are aligned with patient outcomes (4). Whereas the current fee-for-service model rewards a higher volume of services provided, VBC models use outcome

metrics like curative potential, quality of life, and more to determine cost. VBC advocates suggest that pricing gene therapies in this way honors their lifesaving capacity: a one-time cure is worth the million-dollar price tag, weighed against the current standard of care (5).

While VBC models prioritize patient outcomes in theory, they still create high cost barriers for gene therapies, preventing patients from accessing these key cures. **Responsible pricing for gene therapies necessitates a paradigm shift in which preventive care is emphasized in reimbursement models.**

In the United States, providers are paid based on their treatment of a patient's pre-existing or newly discovered condition. Reimbursement correlates with the number of services and/or outcome of services provided. This model has led to reduced uptake of preventive care services— the current system is equipped to handle disease when it happens, not before it happens. Under this model, a gene therapy which can dramatically reduce the burden of a disease on a patient throughout their lifetime is priced according to that burden, requiring cost determinations of the value of a human life via quality-adjusted life-years. Instead, gene therapies can and should be viewed as preventive therapies, which prevent the burden of a disease rather than simply displace it. Accordingly, our healthcare system must shift to account for these new preventive therapies.



This proposition aligns with a broader imperative to prioritize early intervention in our medical system. Preventive care has long been recognized for its potential to significantly reduce long-term healthcare costs by addressing conditions before they escalate, allowing both for reduced lifetime medical expenses and improved outcomes.

Gene therapies can and should be viewed as preventive therapies.

Gene therapies embody this principle, offering the chance to correct genetic anomalies before they manifest as complex medical conditions requiring extensive, continued care.

Already, our system includes provisions for preventive measures which, if applied to gene therapies, could significantly reduce costs. Commercial insurance companies may consider adjusting premiums for gene therapy patients, or might offer incentives for the use of gene therapies akin to wellness incentives for healthy behaviors. On a federal level, the Center for Medicare & Medicaid Services (CMS) can associate cost of gene therapies with population-based risk reduction as opposed to individual patient benefit, grouping gene therapies for rare diseases to reflect the overall population's benefit from these novel cures. CMS has successfully applied similar population health strategies for cardiovascular disease and diabetes prevention (6). Lastly, the federal government could incorporate incentives for pharmaceutical companies to develop preventive therapies, thereby creating a financial incentive for a philosophical shift towards preventive care.

Incorporating gene therapies into preventive care reimbursement frameworks is a necessary step towards fully realizing the patient care benefits of recent groundbreaking progress in genetic engineering. As gene therapy becomes more commonplace and curative solutions for many conditions emerge, it is crucial that payment models evolve in parallel to facilitate the equitable distribution of care. **Framing gene therapies in the broader context of the preventive care movement will improve health equity and make gene therapy a realistic option for patients in need.**

References

1. Center for Biologics Evaluation, Research.

U.S. Food and Drug Administration. FDA; 2024. Approved Cellular and Gene Therapy Products. Available from: https://www.fda.gov/vaccines-blood-biologics/cellular-gene-therapy-products/approved-cellular-and-gene-therapy-products

2. Garrison LP Jr, Lo AW, Finkel RS, Deverka PA. A review of economic issues for gene-targeted therapies: Value, affordability, and access. Am J Med Genet C Semin Med Genet. 2023 Mar;193(1):64–76.

3. Chambers JD, Panzer AD, Kim DD, Margaretos NM, Neumann PJ. Variation in US private health plans' coverage of orphan drugs. Am J Manag Care. 2019 Oct;25(10):508–12.

4. Chen J, Mullins CD, Novak P, Thomas SB. Personalized Strategies to Activate and Empower Patients in Health Care and Reduce Health Disparities. Health Educ Behav. 2016 Feb;43(1):25–34.

5. Garrison LP, Jackson T, Paul D, Kenston M. Value-Based Pricing for Emerging Gene Therapies: The Economic Case for a Higher Cost-Effectiveness Threshold. Journal of Managed Care & Specialty Pharmacy [Internet]. 2019 Jul;25(7). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10397597/

6. Burd C, Brown NC, Puri P, Sanghavi D. A Centers for Medicare & Medicaid Services Lens Toward Value-Based Preventive Care and Population Health. Public Health Rep. 2017;132(1):6.

Correspondence: arya_rao@hms.harvard.edu

Artwork: Composition VIII, 1923 by Vasily Kandinsky. Public domain. Courtesy of Wikimedia Commons.

Safeguarding Gender-Affirming Care in an Era of Uncertainty: Lessons from Massachusetts

Sarah M. Lipson
Harvard Medical School Class of 2026

At Harvard Medical School, we often hear how fortunate we are to learn medicine in Massachusetts. The Commonwealth Fund's most recent health system performance scorecard ranked the state number one overall and highest in insurance coverage, health care affordability, and health care access (1). For many, Massachusetts functions as a medical safe haven – a place where patients travel to receive care unavailable or under threat elsewhere in the country.

Gender-affirming care (GAC) plays a significant role in this narrative. Massachusetts requires state-regulated insurance plans to cover medically necessary GAC, and state laws protect clinicians from professional discipline or civil liability for providing it (2). In July 2025, the legislature passed the Shield Act 2.0, which strengthens legal protections for patients and providers of reproductive health services and GAC (3). On paper, transgender patients in Massachusetts perhaps appear insulated from the escalating national restrictions that have curtailed or eliminated access to GAC in many states.

Yet in October 2025, the fragility of this assumed protection became clear. Fenway Health – a nationally recognized leader in LGBTQIA+ care – announced it would no longer provide GAC to patients under 19 (4). As a Federally Qualified Health Center (FQHC), Fenway relies heavily on federal funding to sustain operations. New federal regulations – which would "deprioritize" organizations that provide GAC to minors – could jeopardize Fenway's FQHC status and the associated funds if they were to continue such care. Fenway's announcement stunned many in Massachusetts who hoped state policy would continue to shield access regardless of federal shifts.

Unfortunately, Fenway was the first, but not the last. Outer Cape Health Services, another

FQHC, subsequently announced it also would discontinue GAC for minors; the organization cited the same federal constraints as Fenway did (5). Reporting conflicts have made it unclear how many FQHCs remain able or willing to continue this care (5-6). As more clinics close, remaining clinics likely will experience greater strain. Patients who previously received timely, geographically accessible care now funnel into fewer systems with longer waitlists, more complex referral pathways, and substantial travel burdens. Notably, this contraction of access occurred despite Massachusetts' strong legal and political commitment to transgender health care.

For medical students who train in one of the most supportive environments in the country, these developments carry a sobering lesson. Many of us viewed Fenway as a model institution for LGBTQIA+ healthcare – one immune to the political and administrative pressures that disrupt GAC elsewhere. Yet recent events underscore that no institution is fully protected. Federal policy can alter access with a speed and reach that state legislation may struggle to counteract.

In light of this reality, the question becomes: what can medical students do?

First, we must resist complacency. We cannot assume that Massachusetts' reputation as a health care safe haven will be permanent. Federal policy changes can rapidly override state-level protections, and the events of 2025 demonstrate how quickly access can shift. As trainees, we must approach our education with an awareness that rights—and health care access—preserved today may require active defense tomorrow.

Second, we must advocate within our institutions. Medical students hold positions on curriculum committees, governance boards, and community partnerships that allow us to shape institutional priorities in meaningful ways. We can push for robust training in gender-affirming care across specialties, help sustain student-run or embedded clinical programs that serve transgender patients, and support faculty who provide this care. Broad internal backing—including from students—can strengthen clinics' ability to maintain services or seek alternative funding mechanisms when external pressures threaten access.

Third, we can support community organizations and patients directly. Sudden clinic closures often leave families confused and distressed, with limited understanding of where to seek care. Students can assist through patient navigation programs, hotline staffing, pro bono advocacy, and collaboration with legal and community groups working to preserve access. These efforts provide immediate support to affected patients while reinforcing the broader ecosystem required to sustain GAC across the state.

Ultimately, we must situate these events within the long arc of public health history. Political structures have always shaped health care access. Local ideals and statutory protections, while essential, do not fully safeguard Massachusetts from the consequences of national policy shifts. If we want this state to remain not only a provider of GAC, but also a refuge for it, we must actively defend the systems that make such care possible.

Massachusetts leads the nation in health system performance, but leadership does not confer invulnerability. Recent events serve as a reminder that protections for GAC—even in dedicated and ostensibly safe environments—can erode quickly. **As future physicians, we bear a responsibility not only to care for patients, but also to safeguard the conditions that enable that care.** The work of ensuring access does not end at the state border; it begins with recognizing that threats can—and have—arrived here, and with our willingness to respond.

++

Author's Update:

Since the completion of this article, the policy landscape described here has evolved. In December 2025, the federal government announced proposed regulatory actions intended

to restrict access to gender-affirming medical care for minors nationwide. These proposals include revision of Medicare/Medicaid participation requirements for hospitals to prohibit enrolled facilities from providing certain gender-affirming treatments to patients under 18 and a separate rule to prohibit the use of federal Medicaid and Children's Health Insurance Program (CHIP) dollars to pay for such care (7). Because Medicare/Medicaid participation underwrites reimbursement across a broad range of hospital services—not solely gender-affirming care—these proposals pose significant financial risk for institutions that continue to offer these services and represent a substantial practical constraint on the continued provision of care. Although these policies remain in the proposal stage and are subject to ongoing legal challenges by multiple states, their announcement already has introduced significant uncertainty for providers and patients, including in states such as Massachusetts that currently maintain statutory protections for access to gender-affirming care.

References

1. Massachusetts. The Commonwealth Fund. https://www.commonwealthfund.org/datacenter/massachusetts (2025).

Campbell. Information for Massachusetts Healthcare Providers Regarding Gender-Affirming Care [Internet]. Office of Massachusetts. Available from: https://www.mass.gov/doc/information-for-ma-healthcare-providers-regarding-gender-affirming-care/download#:~:text=regulated%20health%20insurers?-,Yes.,Yes.

3. Legislature Strengthens Protections for Reproductive and Gender-Affirming Health Care Services. Press Room [Internet]. 2025 [cited 2025 Dec 3]. Available from: https://malegislature.gov/PressRoom/Detail?pressReleaseId=236

4. Shanks J. Sharing an Update About Our Care for Trans Health Patients Under 19 years of Age - Fenway Health [Internet]. Fenway Health. 2025 [cited 2025 Dec 3]. Available from: https://fenwayhealth.org/sharing-an-update-about-our-care-for-trans-health-patients-under-19-years-of-age/

5. Federal Rule Forces Difficult Change, But OCHS Commitment to LGBTQ+ Community Endures - Outer Cape Health Services [Internet]. [cited 2025 Dec 3]. Available from: https://www.outercape.org/2025/10/27/federal-rule-forces-difficult-change-but-ochs-commitment-to-lgbtq-community-endures/

6. Bebinger M. Some Massachusetts health centers stop trans care for minors. WBUR. 2025 [cited 2025 Dec 3]. Available from: https://www.wbur.org/news/2025/10/15/fenway-health-medical-care-halt-transgender-children-massachusetts

7. HHS Acts to Bar Hospitals from Performing Sex-Rejecting Procedures on Children [Internet]. 2025 [cited 2025 Dec 24]. Available from: https://www.hhs.gov/press-room/hhs-acts-bar-hospitals-performing-sex-rejecting-procedures-children.html

Correspondence: sarahlipson@hms.harvard.edu

Artwork: Friendship, 1908 by Pablo Picasso. Public domain. Courtesy of WikiArt.

25 Y(ears) On: The Present and Future of Tissue Engineering

Jules Allbritton-King
Harvard Medical School Class of 2030

In 1997, a segment of the BBC docu-series *Tomorrow's World* aired footage that could have been mistaken for a clip from a Cronenberg film: a white-coated scientist handling a hairless mouse with what looked to be a human ear growing from its back. The "Vacanti Mouse," named for the physicians Charles and Joseph Vacanti, wasn't some miraculous fusion of genetic engineering and developmental biology – it was a rudimentary, yet innovative step in the nascent field of tissue engineering (1).

Tissue engineering as a concept had been around for some time by this point, but the rapid proliferation of images of the Vacanti Mouse undeniably cemented it within the popular imagination. Robert Langer and Joseph Vacanti's seminal 1993 paper in *Science* defined tissue engineering as "an interdisciplinary field that applies the principles of engineering and life sciences toward the development of biological substitutes that restore, maintain, or improve tissue function" (2). This definition hints at the central clinical shortage that spurred the birth of the field: healthy tissue and organs for those in need of grafts or transplants. What if there were off-the-shelf solutions to regrow failing articular cartilage in patients with osteoarthritis, or replace compromised skin in burn victims? **Even more ambitiously, what if we could grow entire lungs, livers, kidneys, or hearts de novo in the lab for patients in need?**

Most approaches to tissue engineering in the early aughts adopted a "top-down" approach, in which macroscopic scaffolds consisting of polymers or decellularized material were seeded with cells to recapitulate a mature tissue. This approach follows the mantra of "cells, scaffolds, and signals", in which cultured primary cells are coaxed to take on tissue-specific behaviors through extracellular matrix-mimicking structural blueprints (scaffolds) and a combination of physical, chemical, and electromechanical cues (signals). Indeed, the Vacanti Mouse's signature dorsal ear was little more than a molded scaffold of PLGA (poly(lactic co-glycolic acid)) seeded with bovine chondrocytes and implanted under the skin of an athymic host animal (1). Despite their relative simplicity, top-down approaches have yielded several FDA-approved therapies using biomaterials with or without the addition of exogenous cells for use in burn wounds, bone grafts, cartilage patches, and peripheral nerve repair (3-6).

Despite these successes, the top-down approach to tissue engineering is inherently limited by its differences from the carefully coordinated developmental processes that form tissue *in vivo*. Seeding cells and cytokines into a scaffold circumvents the orchestrated co-development and co-maturation of the cell populations comprising adult tissue, and so these constructs generally lack innervation, vascularization, and higher-order functions. While advances in 3D printing technologies have yielded a newer generation of tissue constructs with increasing levels of hierarchical complexity and predesigned vasculature for nutrient supply, **these techniques can be likened to trying to build an oak tree from wood, roots, and leaves instead of planting an acorn (7).**

These limitations gave rise to "bottom-up" tissue engineering, which seeks to use the guiding principles of developmental biology to generate macroscopic tissues through the modular assembly of micro-scale scaffolds and progenitor cell populations into discrete functional units of tissue (8). The fundamental difference from top-down tissue engineering is the attempt to recapitulate embryonic tissue morphogenesis, instead of skipping to the adult stage. These approaches were made feasible by the invention of induced pluripotent stem cell (iPSC) technology by Yamanaka et al. in 2007 and became increasingly sophisticated after the commercialization of CRISPR-based gene editing a few years later. Coordinated differentiation of pluripotent or multipotent cell populations by treatment with morphogens and genetic modifications represents a far more straightforward approach to generating heterogeneous functional tissues with complex populations of parenchymal, stromal, vascular, nervous, and immune cells.

While bottom-up approaches towards large-scale tissue replacements are still in their infancy, this paradigm shift towards capturing developmental morphogenesis has led to an explosion of microtissue and organoid-based models, often termed "organ-on-chip" systems. In just over a decade, these technologies have been adapted for a dizzying number of clinically salient research questions including high-throughput screening of cardiac drugs, modeling of tumor metastasis, and mechanistically defining viral infections (9-11). Organoid-based systems are also beginning to emerge in clinical trials databases for applications such as pancreatic islet transplantation and patient-specific testing of chemotherapeutic regimens (12-13). In fact, regulatory agencies have begun establishing standards for organoid research within the last few years as they become increasingly important adjuncts to animal-based disease modeling (14-15).

At present, the most pressing issues facing the generation of large-scale tissue and organ constructs can be divided into two general areas: complexity and scale.

Looking ahead into the next 25 years, I expect to see a convergence of top-down and bottom-up tissue engineering approaches that capitalize on the advantages of each approach to clear these respective hurdles.

First, the micro-scale hierarchical complexity of functional tissue continues to limit the size of most organoid models. Without a functioning vasculature to supply oxygen and nutrients and remove waste, organoids can typically only be sustained at scales of hundreds of microns. Fully-vascularized and perfusable tissue constructs have long been considered the holy grail of tissue engineering, and recent reports of vascular networks and vascularized organoids show a great deal of promise for solving this problem in the coming years (16-17). In terms of parenchymal function, progress in bottom-up tissue engineering has also made great strides in identifying tissue-specific combinations of morphogenic and temporal signaling present during embryonic development, allowing for

defined culture systems to generate functional organotypic subunits (18-20). The next set of challenges will involve determining how to induce further maturation: for example, iPSC-derived cardiac organoids that beat with the strength and regularity of the adult heart, or liver organoids that can produce bile, detoxify culture medium, and carry out their metabolic roles in parallel.

Second is the issue of scale. Concerted efforts in a laboratory setting can generate thousands of organoids for high throughput-experiments, or tens of macroscopic 3D-printed grafts for characterization and animal testing, but traditional monolayer cell culture is incredibly inefficient, especially considering the hundreds of billions of cells comprising an adult-sized human organ. In this arena, we will likely see widespread adoption of industry-style bioreactors for the mass expansion of human cells at cGMP standards. Several groups are tackling both problems at once, leading the charge towards the next generation of tissue engineering by using sophisticated, multi-nozzle 3D printers loaded not with individual cells, but with suspensions of tissue-specific organoids in order to print functional, vascularized subunits that can readily integrate with their neighbors (21-23). Similarly, the use of benchtop bioreactors to massively scale up organoid generation and differentiation is a first step towards whole-organ printing (24).

Just over a quarter-century ago, our most cutting-edge tissue engineering techniques relied on cartilage cells taken from cows, loaded into a primitive mold of an ear, and awkwardly saddled to the back of a mouse host to keep it alive. **Today, we can 3D print bespoke tissue grafts and generate organoids using a patient's own cells to model their disease.** Insights into developmental biology and morphogenesis, paired with efforts to massively scale up the biomanufacturing of human cells, mean that we are hurtling towards a future in which we can generate functional transplants without the need for long organ registries or lifelong immunosuppression.

There are no fundamental technological barriers that have yet to be overcome in the same way that the invention of iPSCs overcame the problem of cell sources – but there are great strides to be made in efficiency and sophistication. By 2050, we may not quite be at the point where industry representatives are present in the OR helping transplant surgeons select appropriately sized off-the-shelf hearts or lungs, but at the current rate that the field is developing, we can hope to at least see FDA approvals or late-stage clinical trials for engineered, transplantable hepatic lobules, cardiac patches, and renal pyramids.

Oh, and even better engineered ears (25).

References

1. Cao, Y., Vacanti, J. P., Paige, K. T., Upton, J., & Vacanti, C. A. (1997). Transplantation of chondrocytes utilizing a polymer-cell construct to produce tissue-engineered cartilage in the shape of a human ear. Plastic and reconstructive surgery, 100(2), 297–304. https://doi.org/10.1097/00006534-199708000-00001

2. Langer, R., & Vacanti, J. P. (1993). Tissue engineering. Science (New York, N.Y.), 260(5110), 920–926. https://doi.org/10.1126/science.8493529

3. Heimbach, D. M., Warden, G. D., Luterman, A., Jordan, M. H., Ozobia, N., Ryan, C. M., Voigt, D. W., Hickerson, W. L., Saffle, J. R., DeClement, F. A., Sheridan, R. L., & Dimick, A. R. (2003). Multicenter postapproval clinical trial of Integra dermal regeneration template for burn treatment. The Journal of burn care & rehabilitation, 24(1), 42–48. https://doi.org/10.1097/00004630-200301000-00009

4. Burkus, J. K., Heim, S. E., Gornet, M. F., & Zdeblick, T. A. (2003). Is INFUSE bone graft superior to autograft bone? An integrated analysis of clinical trials using the LT-CAGE lumbar tapered fusion device. Journal of spinal disorders & techniques, 16(2), 113–122. https://doi.org/10.1097/00024720-200304000-00001

5. Yano, K., Speidel, A. T., & Yamato, M. (2018). Four Food and Drug Administration draft guidance documents and the REGROW Act: A litmus test for future changes in human cell- and

tissue-based products regulatory policy in the United States?. Journal of tissue engineering and regenerative medicine, 12(7), 1579–1593. https://doi.org/10.1002/term.2683

6. Means, K. R., Jr, Rinker, B. D., Higgins, J. P., Payne, S. H., Jr, Merrell, G. A., & Wilgis, E. F. (2016). A Multicenter, Prospective, Randomized, Pilot Study of Outcomes for Digital Nerve Repair in the Hand Using Hollow Conduit Compared With Processed Allograft Nerve. Hand (New York, N.Y.), 11(2), 144–151. https://doi.org/10.1177/1558944715627233

7. Li, S., Liu, S., & Wang, X. (2022). Advances of 3D Printing in Vascularized Organ Construction. International journal of bioprinting, 8(3), 588. https://doi.org/10.18063/ijb.v8i3.588

8. Schmidt, T., Xiang, Y., Bao, X., & Sun, T. (2021). A Paradigm Shift in Tissue Engineering: From a Top–Down to a Bottom–Up Strategy. Processes, 9(6), 935. https://doi.org/10.3390/pr9060935

9. Richards, D. J., Li, Y., Kerr, C. M., Yao, J., Beeson, G. C., Coyle, R. C., Chen, X., Jia, J., Damon, B., Wilson, R., Starr Hazard, E., Hardiman, G., Menick, D. R., Beeson, C. C., Yao, H., Ye, T., & Mei, Y. (2020). Human cardiac organoids for the modelling of myocardial infarction and drug cardiotoxicity. Nature biomedical engineering, 4(4), 446–462. https://doi.org/10.1038/s41551-020-0539-4

10. Kapałczyńska, M., Kolenda, T., Przybyła, W., Zajączkowska, M., Teresiak, A., Filas, V., Ibbs, M., Bliźniak, R., Łuczewski, Ł., & Lamperska, K. (2018). 2D and 3D cell cultures - a comparison of different types of cancer cell cultures. Archives of medical science : AMS, 14(4), 910–919. https://doi.org/10.5114/aoms.2016.63743

11. Lamers, M. M., van der Vaart, J., Knoops, K., Riesebosch, S., Breugem, T. I., Mykytyn, A. Z., Beumer, J., Schipper, D., Bezstarosti, K., Koopman, C. D., Groen, N., Ravelli, R. B. G., Duimel, H. Q., Demmers, J. A. A., Verjans, G. M. G. M., Koopmans, M. P. G., Muraro, M. J., Peters, P. J., Clevers, H., & Haagmans, B. L. (2021). An organoid-derived bronchioalveolar model for SARS-CoV-2 infection of human alveolar type II-like cells. The EMBO journal, 40(5), e105912. https://doi.org/10.15252/embj.2020105912

12. Wang, Q., Huang, Y. X., Liu, L., Zhao, X. H., Sun, Y., Mao, X., & Li, S. W. (2024). Pancreatic islet transplantation: current advances and challenges. Frontiers in immunology, 15, 1391504. https://doi.org/10.3389/fimmu.2024.1391504

13. Verstegen, M. M. A., Coppes, R. P., Beghin, A., De Coppi, P., Gerli, M. F. M., de Graeff, N., Pan, Q., Saito, Y., Shi, S., Zadpoor, A. A., & van der Laan, L. J. W. (2025). Clinical applications of human organoids. Nature medicine, 31(2), 409–421. https://doi.org/10.1038/s41591-024-03489-3

14. Ahn, S. J., Lee, S., Kwon, D., Oh, S., Park, C., Jeon, S., Lee, J. H., Kim, T. S., & Oh, I. U. (2024). Essential Guidelines for Manufacturing and Application of Organoids. International journal of stem cells, 17(2), 102–112. https://doi.org/10.15283/ijsc24047

15. Wu, X., Swanson, K., Yildirim, Z., Liu, W., Liao, R., & Wu, J. C. (2024). Clinical trials in-a-dish for cardiovascular medicine. European heart journal, 45(40), 4275–4290. https://doi.org/10.1093/eurheartj/ehae519

16. Blazeski, A., Floryan, M. A., Zhang, Y., Fajardo Ramírez, O. R., Meibalan, E., Ortiz-Urbina, J., Angelidakis, E., Shelton, S. E., Kamm, R. D., & García-Cardeña, G. (2024). Engineering microvascular networks using a KLF2 reporter to probe flow-dependent endothelial cell function. Biomaterials, 311, 122686. https://doi.org/10.1016/j.biomaterials.2024.122686

17. Gong, L., Zhang, Y., Zhu, Y., Lee, U., Luo, A. C., Li, X., Wang, X., Chen, D., Pu, W. T., Lin, R. Z., Ma, M., Cui, M., Chen, K., Wang, K., & Melero-Martin, J. M. (2025). Rapid generation of functional vascular organoids via simultaneous transcription factor activation of endothelial and mural lineages. Cell stem cell, S1934-5909(25)00221-8. Advance online publication. https://doi.org/10.1016/j.stem.2025.05.014

18. Tekguc, M., Gaal, R. C. V., Uzel, S. G. M., Gupta, N., Riella, L. V., Lewis, J. A., & Morizane,

R. (2022). Kidney organoids: a pioneering model for kidney diseases. Translational research : the journal of laboratory and clinical medicine, 250, 1–17. https://doi.org/10.1016/j.trsl.2022.06.012

19. Lee, J., van der Valk, W. H., Serdy, S. A, Deakin, C., Kim, J., Le, A. P., & Koehler, K. R. (2022). Generation and characterization of hair-bearing skin organoids from human pluripotent stem cells. Nature protocols, 17(5), 1266–1305. https://doi.org/10.1038/s41596-022-00681-y

20. Tanimizu, N., Ichinohe, N., Sasaki, Y., Itoh, T., Sudo, R., Yamaguchi, T., Katsuda, T., Ninomiya, T., Tokino, T., Ochiya, T., Miyajima, A., & Mitaka, T. (2021). Generation of functional liver organoids on combining hepatocytes and cholangiocytes with hepatobiliary connections ex vivo. Nature communications, 12(1), 3390. https://doi.org/10.1038/s41467-021-23575-1

21. Wolf, K. J., Weiss, J. D., Uzel, S. G. M., Skylar-Scott, M. A., & Lewis, J. A. (2022). Biomanufacturing human tissues via organ building blocks. Cell stem cell, 29(5), 667–677. https://doi.org/10.1016/j.stem.2022.04.012

22. Cabral, M., Cheng, K., & Zhu, D. (2024). Three-Dimensional Bioprinting of Organoids: Past, Present, and Prospective. Tissue engineering. Part A, 30(11-12), 314–321. https://doi.org/10.1089/ten.TEA.2023.0209

23. Huang, M.S., Christakopoulos, F., Roth, J.G. et al. Organoid bioprinting: from cells to functional tissues. Nat Rev Bioeng 3, 126–142 (2025). https://doi.org/10.1038/s44222-024-00268-0

24. Ho, D. L. L., Lee, S., Du, J., Weiss, J. D., Tam, T., Sinha, S., Klinger, D., Devine, S., Hamfeldt, A., Leng, H. T., Herrmann, J. E., He, M., Fradkin, L. G., Tan, T. K., Standish, D., Tomasello, P., Traul, D., Dianat, N., Ladi, R., Vicard, Q., ... Skylar-Scott, M. A. (2022). Large-Scale Production of Wholly Cellular Bioinks via the Optimization of Human Induced Pluripotent Stem Cell Aggregate Culture in Automated Bioreactors. Advanced healthcare materials, 11(24), e2201138. https://doi.org/10.1002/adhm.202201138

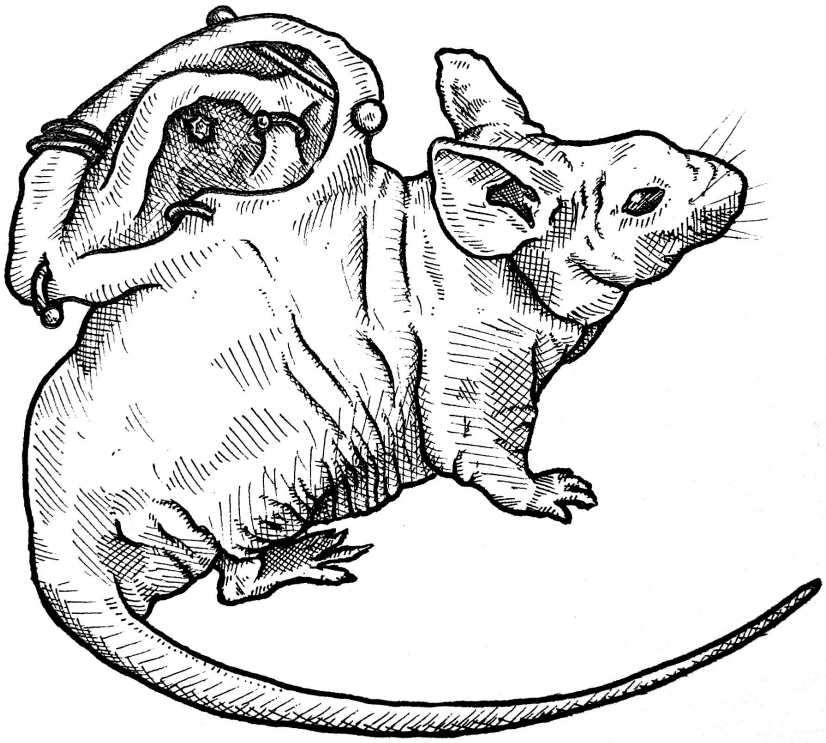
25. Zielinska, D., Fisch, P., Moehrlen, U., Finkielsztein, S., Linder, T., Zenobi-Wong, M., Biedermann, T., & Klar, A. S. (2023). Combining bioengineered human skin with bioprinted cartilage for ear reconstruction. Science advances, 9(40), eadh1890. https://doi.org/10.1126/sciadv.adh1890

Correspondence: jallbrittonking@hms.harvard.edu

Artwork: Auricular Cell, 1894 by Odilon Redon. Public domain. Courtesy of Wikimedia Commons.

The Vacanti Mouse

Jules Allbritton-King
Harvard Medical School Class of 2030
Correspondence: jallbrittonking@hms.harvard.edu



This unlikely mascot of tissue engineering has resurfaced after almost three decades to sit for a portrait for this Special Issue.

The Future of Organ Transplantation: Enhancing Public Trust

Vivian Nguyen
Harvard Medical School Class of 2027

Ever since the first successful kidney transplant at Brigham and Women's Hospital in 1954, organ transplantation has served as a cornerstone of modern medicine, offering life-saving solutions for individuals with end-stage organ failure (1). It stands at the forefront of innovation and scientific discovery, and we, as future physicians and surgeons, hold a responsibility to better the system and improve outcomes for patients.

No system is perfect, as many in the medical field know. With any system that exists, there coexists the need for systemic reforms, technological advancements, and improved public understanding to ensure the continued success and ethical integrity, including in transplantation practices.

When I first started to write this essay, I wanted to focus on the future of transplantation medicine as it relates to technological advancements, including methods to improve the viability of donor organs and innovative partial transplantation approaches such as the partial heart transplantation program currently being trialled at our very own Boston Children's Hospital.

Far more pressing in the next 25 years, however, are issues surrounding the ethics of transplantation. I would be remiss to write an article about the future of transplantation without addressing the recent article from *The New York Times* which highlights rare yet disturbing instances in which the first steps in the process of organ donation were initiated while patients were still alive or showing signs

of recovery, particularly under donation-after-circulatory-death (DCD) protocols (2).

This article in particular has understandably shaken public confidence in the organ donation system; additional negative media stories further risk erosion of that trust. **But it is important to first emphasize that organ donations save lives.** There are over 100,000 people on the national transplant waiting list, with 13 people dying each day waiting for a transplant (3). Every donor can save up to 8 lives and improve the quality of over 75 other lives with tissue donations (3).

Organ donations save lives.

The *New York Times* article highlights a miniscule percentage of all organ recoveries performed in the United States, and there are countless protections and safeguards in place to prevent such occurrences (4-6). These protections are of course imperfect, as these instances highlight. In the next 25 years, we must improve upon these to mend public trust and to bolster protection for patients.

Let us first examine current protocols. First, physicians involved in patient care do not know about a patient's donor status during treatment and act independently from the organ procurement team. This safeguards against any potential conflicts of interest, ensuring that patient care decisions are made solely based on medical necessity.

Within the organ procurement team, there are highly subspecialized roles. At New England Donor Services, for example, a family resource coordinator who specializes in difficult conversations is the initial and primary contact with the family. With every organ from every donor, a separate match list is run to make sure that the recipient is compatible from a medical perspective4,7. When a match list is run, medical institutions are informed of the organ offer so they can provide preliminary acceptance or rejection of the organ7. The surgeons who procure the organs are not in the room at the time of extubation or the time of death to prevent conflicts of interest. Aftercare specialists provide services for donor families to help with the grieving process. The system is one made of many gears, with multiple necessary roles to help it run smoothly.

Finally, the organ procurement system that interacts with organ donors and their families is entirely separate from the transplant surgeons performing the transplant itself (7). There is little to no overlap, other than the organ procurement organization making the offer to institutions (7). Out-of-order allocations are rare and only occur when the organ is unlikely to be allocated in time to prevent organ non-utilization (7-8).

Future public education campaigns should focus on dismantling misinformation and highlighting the ethical safeguards inherent in the system as we take steps to rebuild this trust. Transparency is crucial. Institutions must openly communicate the steps taken to prevent such incidents, including the implementation of enhanced training for medical staff, the adoption of monitoring technologies, and the establishment of independent oversight committees. **By fostering an environment of openness and accountability, the medical community can work towards restoring public confidence in the organ donation process and exciting advancements being made to increase the number of lives saved each year.**

The future of organ transplantation holds immense promise, driven by technological innovations and a restoration of public trust. Embracing advancements allows the medical community to continue offering hope and improved quality of life to individuals in need of organ transplants. Each organ donor and donor family are heroes. Even at one of the most emotionally devastating moments in their lives, they chose to be compassionate to others and generous enough to give an incredible gift to save and improve the lives of others. **With their last moments, they chose to donate life.**

References

1. United Network for Organ Sharing. History of transplantation. UNOS. Published online.

Accessed December 11, 2025. https://unos.org/transplant/history/

2. Rosenthal BM, Tate J. A Push for More Organ Transplants Is Putting Donors at Risk [published July 20, 2025]. The New York Times. Accessed December 11, 2025. https://www.nytimes.com/2025/07/20/us/organ-transplants-donors-alive.html

3. Donate Life America. Organ, Eye and Tissue Donation Statistics. https://donatelife.net/donation/statistics/. Updated March 2024. Accessed December 11, 2025.

4. Health Resources and Services Administration (HRSA). Strengthening Organ Donation and Procurement Safety. https://www.hrsa.gov/optn/policies-bylaws/policy-issues/strengthening-organ-donation-and-procurement-safety. Updated December 9, 2025. Accessed December 11, 2025.

5. Glazier A, JD, MPH. OPO and Transplant Policy. Lecture presented at New England Donor Services Galen V. Henderson, MD Program; June 10, 2025; Waltham, MA.

6. Asfaw B, Whelan A, Jones K, Shaughnessy C. Quality and Safety in Organ Donation. Lecture presented at New England Donor Services Galen V. Henderson, MD Program; June 12, 2025; Waltham, MA.

7. Wojtowicz J. Seminar on Donor Referral & Organ Allocation. Lecture presented at New England Donor Services Galen V. Henderson, MD Program; June 10, 2025; Waltham, MA.

8. Curran C. Optimizing Organ Utilization. Lecture presented at New England Donor Services Galen V. Henderson, MD Program; June 12, 2025; Waltham, MA.

Correspondence: vnguyen@hms.harvard.edu

Artwork: Icarus, 1943-1944 by Henri Matisse. Public domain. Courtesy of WikiArt.

Returning to the Body: Potential Reforms in Medical Education

Shreyas Rajesh
Harvard Medical School
Class of 2028

During the COVID-19 pandemic, physicians faced a doubled challenge. Inundated by more patients than hospitals had been constructed to accommodate, providers were also tasked with providing robust care in the absence of scientifically-tested therapies. How did excellent doctors prevail? Knowing the guidelines for the treatment of respiratory diseases could only get one so far; facing an austere absence of scientific insight, it was a thorough understanding of first principles that enabled physicians to provide the best possible care for patients under uncertain circumstances.

As globalization, climate change, chemical exposure, and increased zoonotic contact increase the frequencies at which new diseases impact populations, providers can expect to frequently encounter illnesses that challenge their knowledge bases (1). Just as new diseases will strike terror in us, so too will new therapies dazzle us. Who knows what surgeries will have been invented, what preventive screening measures adopted, or what miraculous drugs will be easily available in this new future? The world in 2050 will look radically different from our own, and to best prepare for it, physicians must know much more than the diseases of today.

Going forward, we can expect one reliable constant: the human body. Timescales of innovation may be rapidly compressing, but timescales of physiological evolution likely will not be. Instead of focusing medical education on each new treatment introduced, to best prepare future physicians, we must center the future of medical education on a deep understanding of the human body.

This pedagogy must be differentiated from a disease-focused one. In the traditional disease-centered approach, students learn to identify constellations of symptoms and then arrive at a diagnosis and understanding of the pathology. This practice is the entire basis of licensing exams and for an appreciable reason: pattern recognition and diagnosis is the "bread and butter" of medicine. Yet in a world of escalating technologies and rapidly developing diseases, this

approach is not good enough.

I instead argue for an organ systems-focused approach, in which normal physiology is taught and then disease is explained in the context of the baseline state. This is not a revolutionary proposition. Many medical schools today already deploy an organ systems-first approach to education (2). These approaches definitionally focus on the body as the unit of medicine, emphasizing, organ-by-organ, normal physiology and its pitfalls in disease.

To enact this kind of curricular reform, we must reimagine the medical school classroom itself.

No one learns to problem solve by attending a lecture. During the undergraduate medical education years, students must be tasked with thinking critically about abnormal and normal systems. This means that class time should focus on problem-solving, and assessment should provide students an opportunity to demonstrate mastery of a system by elucidating its component parts in-depth. The way to build deep thinking is to create educational opportunities that invite student engagement; case-based, small-group learning modules are imperative.

These are two tangible interventions that we might adopt now to bring us to the future of medicine as it should be in 2050. The emphasis on critical thinking is, fortunately, already being embraced. The University of Vermont at Larner College of Medicine (UVM) eliminated almost all its didactic sessions in 2019, in a model that prioritizes cased-based learning and problem solving, both in teams and in small-group learning. In 2006, Case Western University launched its Case Inquiry Teams (Case IQ), involving groups of eight to ten students who work in-close contact with the professor (4). This structure is also the bedrock of the Harvard Medical School Pathways curriculum. Harvard's distinctive case-based collaborative learning format emphasizes deep learning through active problem solving and engagement, and courses emphasize physiology (5). While UVM, Case Western Reserve, and Harvard are distinct in their approach, numerous other schools—including Dell Medical School, Washington University in St. Louis, University of Michigan, and Yale University—have embraced this pedagogy (6-9). The replication of this model has shown that it is at least partially feasible at a wide range of institutions.

The second intervention is the reversal of a trend. Cadaver labs seem to be on the way out; I propose that in the future, they should return (10). **There is no way to understand anatomy without immersion.** Actual time spent with the donor enables one to develop an appreciation for the intricacies of how organ systems relate to each other. While conceivably, some futuristic simulations might provide a similar experience, the cadaver also is the medical student's first teacher—the first body in their hands, and for many, the first time they might have come so close to death.

Naturally, the question arises: if the focus is pure physiology, with disease treatment coming secondarily, will future physicians be ill-equipped to leverage novel treatments when the time comes? The medical classroom I envision here does not eschew the capacity to diagnose, nor does it inadequately prepare students to understand drug mechanisms. But consider a software program that, upon the typing of a word such as "IBD" immediately offers the name of multiple drugs with corresponding clinical trials. This vision is not bold, as it is where electronic medical records are headed within the next five years. The artificial intelligence revolution will likely enable providers to more quickly and more accurately access insights from the latest research. **Diagnostic excellence, physician's intuition, and an innate knowledge of physiology will be paramount, and knowing treatments will be less important than knowing how to critically navigate new information.**

So, how do we get here? One can hardly envy a medical dean, who must negotiate the inverse

pressures to at once prepare students to think critically and understand deep physiology while simultaneously ensuring that board scores do not suffer. To truly revolutionize medical education, we need to adopt an ambitious—and frankly, expensive—type of NBME exam. Future board exams should present future doctors with questions that interrogate underlying physiological mechanisms and cases, not just one-answer questions with finite options. Students should be interrogated to see how much they understand the physiology, not just on whether they can regurgitate information.

2050 will give physicians many new resources to improve the care and wellbeing of patients, and it will demand a new set of skills. To succeed, we must reinforce the idea of medicine as a study of the human body, asking our students to think deeply and critically about human physiology from first principles. There are no doubt challenges to revolutionizing a system of medical education and assessment, but we already have schools that have successfully embraced the idea of a problem-based approach to education. Let us hope to stay on this course to best care for the patients of the future.

References

1. Hunter PR. Future disease burden due to the rise of emerging infectious disease secondary to climate change may be being under-estimated. Virulence. 2025 Dec 31;16(1):2501243.

2. Xia L, Jiang B, Zhang J, Yang K, Zhang Q, Zhu PY. Organ-System-Based Curriculum in Medical Education: A Scoping Review. Adv Med Educ Pract. 2025 Sept;16:1675–81.

3. Noonan K. Vermont Medical School Ceases All Lectures from Curriculum and Adopts "Active Learning" Techniques for Teaching Next Generation of Physicians [Internet]. Dark Daily. 2017 [cited 2025 Dec 20]. Available from: https://www.darkdaily.com/2017/12/01/vermont-medical-school-ceases-all-lectures-from-curriculum-and-adopts-active-learning-techniques-for-teaching-next-generation-of-physicians-1130/

4. Case Inquiry Program | Curriculum | Case Western Reserve University [Internet]. Curriculum | Case Western Reserve University. 2025 [cited 2025 Dec 20]. Available from: https://case.edu/medicine/curriculum/curriculum-overview/foundations-medicine-health/case-inquiry-program

5. Schwartzstein RM, Dienstag JL, King RW, Chang BS, Flanagan JG, Besche HC, et al. The Harvard Medical School Pathways Curriculum: Reimagining Developmentally Appropriate Medical Education for Contemporary Learners. Acad Med. 2020 Nov;95(11):1687–95.

6. Leading EDGE Curriculum [Internet]. Dell Medical School. Available from: https://dellmed.utexas.edu/education/academics/undergraduate-medical-education/leading-edge-curriculum

7. MD Program Curriculum Overview & Highlights [Internet]. Umich.edu. 2025 [cited 2025 Dec 20]. Available from: https://medschool.umich.edu/programs-admissions/md-program/md-curriculum/md-program-curriculum-overview-highlights

8. The Yale System [Internet]. medicine.yale.edu.https://medicine.yale.edu/md-program/admissions/yale-system/

9. Curriculum | MD Program | Washington University in St. Louis [Internet]. Wustl.edu. 2025. Available from: https://md.wustl.edu/curriculum/

10. Nadir Al-Saidi. Medical schools are eliminating the use of cadavers, and that's a shame. STAT. 2025.

Correspondence: shreyas_rajesh@hms.harvard.edu

Artwork: Portrait of Pablo Picasso, 1912 by Juan Gris. Public domain. Courtesy of Wikimedia Commons.

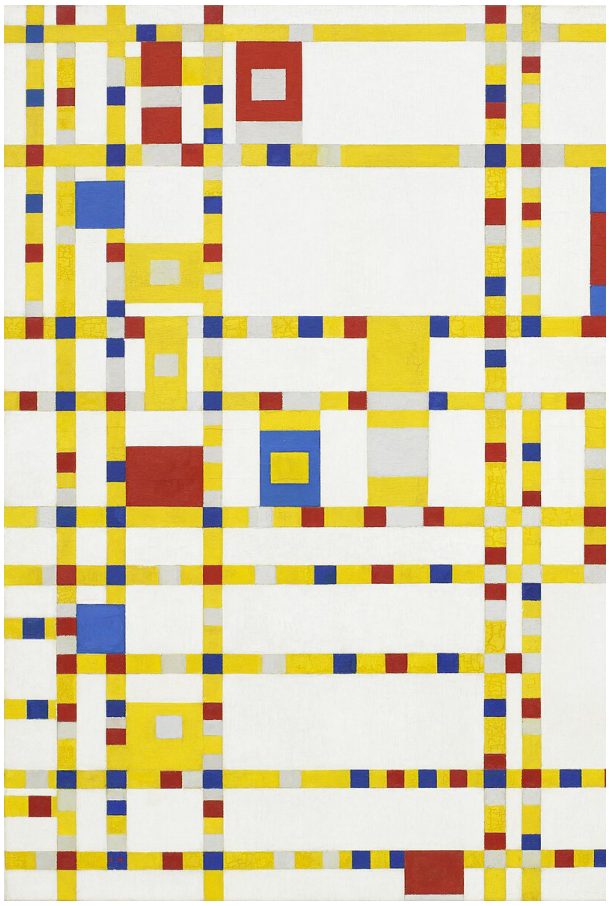
Closing the Data Divide in Healthcare

Isani Singh
Harvard Medical School Class of 2027

Starting clinical rotations in medical school is a very unique experience. You see diseases you may have never learned about, you are expected to understand a language you don't yet speak, and you are being constantly evaluated. I expected all of these things. What I did not expect was that learning the electronic medical record (EMR) would be one of the biggest challenges of the year.

I started my rotations at Brigham and Women's Hospital, where we use Epic, a common EMR system. My next rotation was at Boston Children's Hospital, which at the time used Powerchart. I had just gotten familiar with drafting notes in Epic, and everything changed the next week. Two weeks into my time at Boston Children's, they transitioned from Powerchart to Epic. As a medical student, it's not surprising I was struggling with these changes. What was surprising, however, was that everyone around me was too.

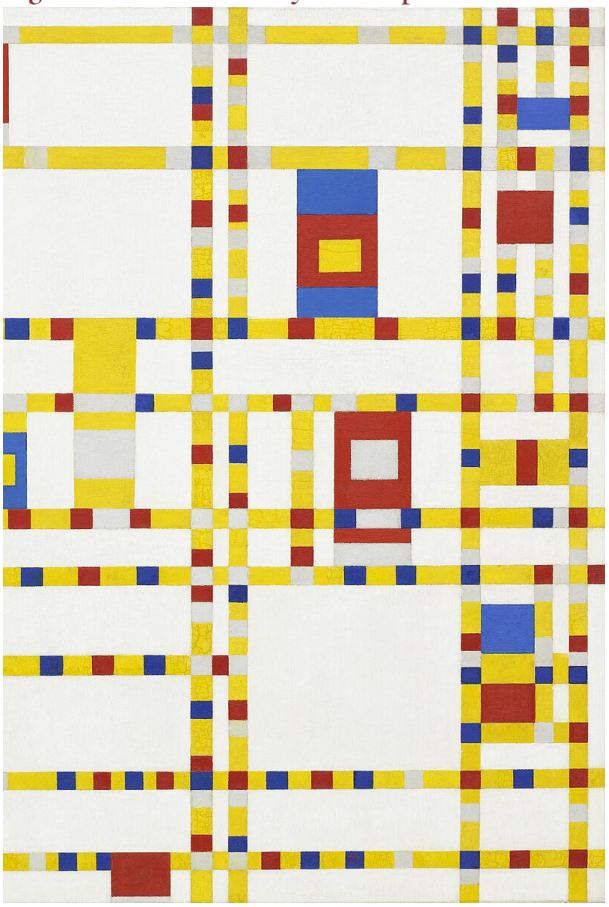
Charting is a major responsibility of the modern physician. When patients are unable to tell their own stories, the clinician must rely entirely on the medical record to learn the information necessary to provide safe and effective care. However, despite the importance of the EMR, it is not standardized (1). Hospitals across the country use different systems, and even those that use the same system may not have seamless



data sharing (1).

This is a problem for three reasons. First, without a universal data system, it is impossible to elegantly coordinate care. Physicians have no choice but to reorder tests or retry treatments unnecessarily when information is not transmitted effectively, contributing to waste in the healthcare system. Second, this can pose real risks to patient safety.

For example, a patient may have an allergy to an antibiotic. It is unconscionable to imagine that this allergy may be documented by previous healthcare providers in just a city over, but that this patient may nonetheless suffer a life-threatening reaction because that information wasn't available. Finally, the lack of a universal data system is a hindrance to health equity. Unfortunately, many patients have not had access to resources to achieve strong levels of health literacy. It is inevitable that these patients are the same ones who may not be able to recount their history to a physician and thereby may receive lesser quality care. **A universal data system levels the playing field, giving all providers all the information they need to take care of patients, regardless of where they show up for care.**



As the capabilities of artificial intelligence grow, now is the ideal time to work towards a universal data system. In a universal data system, secure, real-time learning could occur on patient data to inform continuous care improvement (2-3). If implemented, the possibilities are limitless. AI, with the help of real humans assessing its results, could tell us which hospitals may need certain resources, what types of biases may be impacting care, and which patients may have diagnoses that haven't yet been considered.

I imagine there are many reasons that a universal data system doesn't yet exist. One of those reasons might be that current vendors profit from their proprietary systems and are thus disincentivized from allowing interoperability. Surmounting this would likely require federal mandates and regulatory oversight. I also empathize with concerns some may have over data privacy. Questions surrounding who has access to the data and how it may be used are important to consider. I think there would have to be strict limits of the commercial use of this data as well as the ability for patients to see exactly how their data is being used. On the provider side, there may be resistance to the AI aspect I proposed specifically. I think some of my colleagues would worry about the real-time continuous care improvement increasing workload or threatening their independence by making rigid suggestions. As with all uses of AI, it is critically important to co-design tools with the critical stakeholders and frame the data as a way to reduce harm as well as workload, and importantly not as a means to police decision making.

In the status quo, patients are receiving worse quality care and healthcare costs are rising, in part because of the lack of unity across health data systems. We are also missing out on opportunities to improve care by failing to leverage new tools to analyze the vast amount of data that healthcare professionals spend much of their time creating.

Our generation must build the health system we wish we had because our patients cannot wait another decade.

If we dare to build a universal healthcare data system, we choose a future where every patient encounter becomes a step toward safer, smarter, more equitable care.

References

1. Turbow S, Hollberg JR, Ali MK. Electronic Health Record Interoperability: How Did We Get Here and How Do We Move Forward? JAMA Health Forum. 2021 Mar 17;2(3):e210253.

2. Kaissis GA, Makowski MR, Rückert D, Braren RF. Secure, privacy-preserving and federated machine learning in medical imaging. Nat Mach Intell. 2020 Jun;2(6):305–11.

3. Rieke N, Hancox J, Li W, Milletarì F, Roth HR, Albarqouni S, et al. The future of digital health with federated learning. npj Digit Med. 2020 Sep 14;3(1):119.

Correspondence: isani_singh@hms.harvard.edu

Artwork: Broadway Boogie Woogie, 1942 by Piet Mondrian. Public domain. Courtesy of Wikimedia Commons.

Learn more and
submit your work at
hmsreview.org

Connect with us:

@HMSReview

HMSR