Global Perspectives On Limb Preservation: A Comparative Analysis of Health System Models and Clinical Realities

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Abstract: Limb preservation has emerged as a critical benchmark, and a suggested metric, of health-care system performance, reflecting the interplay of early detection, multidisciplinary coordination and reimbursement alignment. Despite advances in vascular and wound care, profound global disparities persist in lower-extremity amputation (LEA) rates. This comparative narrative review examines how the four dominant global health-care financing models—Beveridge, Bismarck, National Health Insurance (NHI), and Out-of-Pocket—influence access to limb salvage services and long-term clinical outcomes. Two contrasting regional paradigms anchor this analysis. The first is the Middle East and North Africa (MENA) region, which faces a dual burden: the world's highest proportional diabetes prevalence and a 1.39% annual increase in LEA incidence driven by political instability and armed conflict. Within MENA, marked heterogeneity exists. The second is the United States, which presents a contrasting picture of structural complexity: a system that achieved documented declines in major amputation rates through the early 2010s (Goodney et al., 2013) before experiencing a subsequent reversal, with current combined amputation rates approximately two to three times those of peer nations (Weaver et al., 2024). Universal drivers of limb loss identified across all systems include delayed patient presentation, socioeconomic disparities, deficient wound education and misaligned reimbursement.

Key words: *limb preservation, lower-extremity amputation, global health systems, diabetic foot, value-based care, MENA region, Egypt, universal health insurance, financing models*

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Traditionally, health-care system evaluations rely on complex, multi-layered metrics including administrative overhead, the prevalence of chronic conditions like heart disease and obesity, and broad measures of access and equity. However, this study posits a more singular, high-stakes benchmark: the amputation rate. We argue that a chronic wound—the primary precursor to most preventable amputations—is not merely a localized dermatological issue, but the physical manifestation of a systemic failure in chronic disease management. Non-traumatic amputation highlights the critical gap between preventive care and late-stage clinical failure. It serves as a finite measure that encapsulates the synergy—or lack thereof—between patient health literacy, provider education, care coordination and financial incentives.

Limb salvage outcomes are dictated by the national financial and structural architectures of a health-care system (Commonwealth Fund, 2025). The global urgency of this issue is underscored by staggering statistics: the International Diabetes Federation reports that "one limb is lost to diabetes every 30 seconds" (International Diabetes Federation, 2021), yet up to 85% of these amputations are considered preventable through timely, multidisciplinary intervention (American Diabetes Association, 2022).

Consequently, a detailed analysis of global health-care systems through the lens of amputation incidence is not only worth scrutiny but essential for future policy reform. Using amputation incidence as a benchmark, this analysis addresses both traumatic and non-traumatic limb loss, exploring how distinct regions navigate unique structural struggles.

Objectives

This analysis pursues the following research aims:

- To characterize the four primary global health system financing models (Beveridge, Bismarck, NHI and 'Out-of-Pocket') with respect to their structural, payment and amputation rate profiles.
- To examine educational disparities across systems regarding physician training in chronic wound care and amputation prevention.
- To identify the primary structural and metabolic drivers of preventable amputation across financing models, including systemic fragmentation and misaligned reimbursement.
- To analyze the intersecting structural challenges of the MENA region alongside the implications of the US transition to Value-Based Care (VBC) for global limb preservation policy.
- To advance the amputation rate as a validated primary benchmark of health system performance and a foundation for evidence-based global health equity advocacy.

Section I. Methods

This study employs a comparative narrative review methodology to evaluate how the structural and financial architecture of global health-care systems influences lower-extremity amputation (LEA) rates and limb preservation outcomes. A systematic search of peer-reviewed literature was conducted across PubMed, MEDLINE, PubMed Central and Google Scholar, supplemented by grey literature from the International Diabetes Federation, the World Health Organization, the Commonwealth Fund, the Centers for Medicare & Medicaid Services and relevant national health authorities. Search terms included combinations of: "lower extremity amputation," "limb preservation," "diabetic foot," "health-care systems," "Beveridge model," "Bismarck model," "universal health insurance Egypt," "MENA amputation," "value-based care" and "amputation prevention." Literature published from January 2000 through March 2026 was considered eligible; seminal foundational sources predating this range were included where their clinical or policy relevance warranted citation. Studies were selected based on relevance to health system financing models, amputation epidemiology, diabetic foot management, or limb salvage outcomes. Case reports were excluded. Data were synthesized thematically across five domains: health system model characteristics, metabolic burden, structural barriers to care, regional case studies (MENA and the United States) and emerging reform trajectories. No patient-level data were accessed; ethical approval was not required for this review.

Limitations And Metric Justification

The authors acknowledge that the lower-extremity amputation (LEA) rate as a cross-national health system indicator requires careful methodological interpretation. Differences in coding practices, definitions of major versus minor amputation and population-level diabetes prevalence introduce comparability constraints that have been noted in the health economics literature (Jeffcoate & van Houtum, 2004; Carinci et al., 2016). This analysis therefore, frames LEA rate not as a simple clinical output variable, but as a composite downstream indicator of systemic performance across the full cascade from chronic disease prevention through wound detection, early revascularization, infection management and multidisciplinary care coordination.

The diabetic foot ulcer—the primary precursor to the large majority of non-traumatic lower-extremity amputations—is not a dermatological event in isolation. It is the biological endpoint of a cascade of unmanaged upstream failures: peripheral neuropathy arising from chronically uncontrolled hyperglycemia; peripheral arterial disease eliminating tissue perfusion; recurrent undetected micro-trauma in the setting of absent protective sensation; and the compounding effects of nutritional insecurity, limited mobility, low health literacy, delayed care-seeking and inadequate access

to vascular and wound specialists (Armstrong et al., 2017; Hicks et al., 2023). Critically, applying a wound product to a patient with unresolved ischemia and unmanaged blood glucose does not heal the wound; the metabolic environment must be corrected concurrently. A systematic review and meta-analysis of 57 studies demonstrated that multidisciplinary teams integrating glycemic control, vascular management, infection treatment and wound care simultaneously reduced major amputation risk by 48% compared to siloed care (Santema et al., 2021). Amputation, therefore, occurs not because of wound complexity alone, but because the surrounding health system failed to intervene at each prior stage of this cascade—a failure that is structural, financial, educational and social in its origins.

The metric's legitimacy as a systems indicator is further supported by the Organization for Economic Co-operation and Development (OECD), which formally included diabetes-related LEA rates in its Health Care Quality Indicators project as early as 2006. An analysis of 26 OECD nations found that, after controlling for structural variables, systems financed by public taxation demonstrated significantly lower amputation rates than insurance-based counterparts, encouraging continued exploration of LEA rate as a primary indicator in the OECD's health system quality matrix (Carinci et al., 2016). The foundational case for amputation as a quality marker was established by Jeffcoate and van Houtum (2004) in *Diabetologia*, who documented that LEA rates reflect not disease severity alone, but the full architecture of care: access to primary care, referral speed, specialist availability and prevailing clinical practice. A health system that intercepts chronic disease early, deploys preventive screening, trains its clinicians to recognize the wound as a systemic signal and coordinates multidisciplinary care consistently produces lower amputation rates—regardless of baseline metabolic burden. The rate is the verdict.

Section II. Comparative Analysis Of Global Health Models

The efficacy of limb preservation is fundamentally tethered to the structural and financial architecture of a nation's health-care system. While the clinical goal—preventing amputation through revascularization and wound care—is universal, the delivery of that care is dictated by how a system is funded and managed. Globally, health-care systems generally align with one of four foundational models, each presenting distinct advantages and barriers for the limb-salvage patient (Wendt et al., 2009; Murray & Frenk, 2000). (See Table 1.)

Table 1: Comparative Framework of Global Healthcare Financing Models

Model Type	Funding Source	Key Strength	Primary Barrier
Beveridge (Socialized Medicine)	General Taxation	Standardized Protocols & Preventive Pathways	Wait Times for Specialist Access
Bismarck (Social Health Insurance)	Payroll Deductions (Private, Non-Profit)	Rapid Specialist Access & High Patient Choice	Administrative Complexity
National Health Insurance (NHI / Single-Payer)	Government-Run Insurance	Cost Efficiency via Single-Payer Leverage	Regional Resource Gaps
Out-of-Pocket (Low-income Nations)	Direct Patient Payment	None (No Formal Insurance Structure)	Late-Stage Presentation; No Safety Net
U.S. Mixed (Fragmented Mosaic)	Multi-Payer Fragmented (Private, Public, Self-Pay)	Innovation & Advanced Technology	Inequity, Fraud, & Misaligned Incentives

Key Strengths Primary Barrier Out-of-Pocket (high risk) U.S. Mixed (caution)

The Beveridge Model (Socialized Medicine)

Named for William Beveridge, the architect of the UK's National Health Service (NHS), this model treats health care as a public service financed through general taxation. Primary examples include the UK, Spain, New Zealand and Scandinavia. Hospitals are largely government-owned, and many clinicians are state employees. The government acts as the sole payer, allowing for centralized control over pricing and standardized clinical pathways (Anandaciva, 2023). The strength of this model lies in its high integration of care and population-wide preventive screening. However, budget-driven caps often lead to significant wait times for "elective" specialized wound clinics. In the context of limb salvage, delays in accessing specialists can turn a manageable foot ulcer into a life-altering amputation (Commonwealth Fund, 2025). Their standardized preventive care results in overall lower amputation rates (2.9–8.3 per 100K) (Gunja et al., 2024; Anandaciva, 2023).

Case Study: The UK NHS Integrated Diabetic Foot Care Pathway. The UK NHS offers one of the most instructive evidence-based case studies of the Beveridge model's capacity to systematically reduce amputation through structured pathway integration. The foundational model was established in 1981 at King's College Hospital, London, with the creation of the UK's first dedicated multidisciplinary diabetic foot clinic. Within three years, the rate of major amputations at that institution had halved (Edmonds et al., cited in Diabetes UK, 2024). Building on this evidence, the NHS subsequently embedded the multidisciplinary foot team (MDFT) within its national commissioning framework, mandating that all areas provide a NICE-compliant foot clinic with weekly appointments, no waiting list for urgent referrals and defined rapid referral pathways from primary to specialist care (NICE, 2015).

The real-world impact of this pathway architecture is documented through regional NHS peer review data. In the South West of England, a peer review program evaluating 14 NHS providers found a strong inverse correlation between the provision of 10 key diabetic foot care services and major amputation rates; sites that implemented service improvements achieved measurable reductions in major amputation incidence within two years (Paisey et al., 2018). Critically, the economic case for this investment is unambiguous: the annual NHS cost of diabetic foot ulceration and amputation in England was estimated at between £837 million and £962 million in 2014–2015, exceeding the combined cost of breast, prostate and lung cancer care, with 60% of expenditure occurring in preventable community and outpatient settings (Kerr et al., 2019). It should be noted, however, that NICE pathway compliance and diabetic foot outcomes vary considerably across NHS regions; geographic inequities in specialist access and audit compliance remain active areas of NHS quality improvement (Paisey et al., 2018).

The Bismarck Model (Social Health Insurance)

The primary examples of the Bismarck model include Germany, Japan, France and Switzerland. This model utilizes an insurance system financed jointly by employers and employees through payroll deductions. Unlike the US commercial market, these insurers are strictly non-profit and must cover all citizens. The Bismarck model typically offers high levels of patient choice and rapid access to specialists with high administrative efficiency and access to care. These factors ensure high-risk patients, like those with PAD, receive interventions before limb-threatening ischemia can occur (Gunja et al., 2024; Wendt et al., 2009; OECD, 2025).

Case Study: Germany's DRG System, Podological Care, and Amputation Trends. Germany's Bismarck system provides a particularly granular case study in how Diagnosis-Related Group (DRG) data—mandated from more than 99% of German hospitals—can be leveraged as a real-time quality surveillance instrument for amputation prevention. Among people with diabetes in Germany, major amputation rates declined significantly from 2008 to 2012, with the relative risk of major LEA comparing diabetic to non-diabetic populations decreasing at approximately 4% per year (Claessen et al., 2018). A longer-term national analysis documents

major amputations decreasing from 18.6 to 17.5 per 100,000 in men and 6.8 to 5.2 per 100,000 in women between 2015 and 2022 (Tuncer et al., 2024). A notable contributor was the concurrent expansion of statutory podological foot care (PFC) visits reimbursed through the German social health insurance system. Analysis found a significant inverse association between increasing PFC expenditure and decreasing major amputation rates (Kröger et al., 2014). Notably, German amputation rates, while on a declining trajectory, remain higher than those observed in Scandinavian Beveridge-model countries, indicating that Bismarck-model structural advantages have not yet fully converged with the lowest-performing peer nations (Tuncer et al., 2024).

National Health Insurance (NHI) Model

The NHI model—exemplified by Canada, Taiwan and South Korea—blends the private-provider flexibility of Bismarck with the single-payer efficiency of Beveridge. Health care is delivered by private-sector providers, but the bill is paid by a government-run insurance program. Universal coverage ensures basic diabetic foot care is accessible and, in preliminary work, leveraging single-payer data to target high-risk populations has shown promise for predictive survival modelling of diabetic foot complications, potentially enabling earlier intervention (Ramachandram et al., 2025); the system maintains a stable amputation rate of 5.0–7.0 per 100K across these nations.

Case Study: Taiwan and Canada—Single-Payer Leverage and Limb Preservation. Taiwan's NHI system, which covers approximately 98% of the population, provides a compelling demonstration of how single-payer data architecture enables targeted intervention. Among patients with diabetic foot disease, the amputation rate decreased significantly from 24.9% to 17.5% of cases between 2005 and 2014 (Lin et al., 2019; Chen et al., 2019). Taiwan's NHI also introduced a pay-for-performance (P4P) program linked to reduced incidence of lower-extremity amputations—an example of how a single-payer system can embed outcome-based financial mechanisms without the administrative fragmentation that undermines such programs in multi-payer environments.

Canada's NHI system presents a more complex picture—one that illustrates both the protective capacity of universal coverage and its limitations when not paired with integrated specialty care infrastructure. A national cohort study found that major amputation rates related to diabetes decreased over time, with reductions observed in Ontario, Manitoba and Saskatchewan—provinces with more developed integrated care networks (Jalayeri Nia et al., 2025). This provincial variation underscores that single-payer financing is a necessary, but not sufficient, condition for limb preservation: the distribution of vascular specialists, diabetic foot teams and structured referral pathways within a universal system determines whether coverage translates into salvaged limbs.

The Out-of-Pocket Model

In many developing nations, there is no formal state-wide insurance apparatus. Access to care is determined solely by the ability to pay at the point of service. Examples include rural regions of Africa, India and parts of South America, though within-region variation is considerable and certain sub-national contexts demonstrate markedly better outcomes than regional averages would suggest. Globally, over 1.6 billion people face extreme financial hardship due to these medical expenses (OECD, 2025). In these regions, limb preservation is frequently viewed as a luxury. Late-stage clinical presentation is the norm, and primary amputation often becomes the default solution for patients who cannot afford complex revascularization (Moxey et al., 2011).

The US Mixed Model

The United States operates a fragmented mosaic of all four models, and its amputation rate trajectory reflects a pattern of notable complexity rather than unidirectional failure. Longitudinal Medicare data document a meaningful period of progress: Goodney et al. (2013) demonstrated that major lower-extremity amputation rates declined substantially among Medicare beneficiaries from

the early 1990s through the early 2010s, concurrent with increased rates of both surgical bypass and endovascular revascularization—a finding that underscores the measurable impact of expanded vascular intervention on limb outcomes within the US system. However, this improvement was not sustained. Weaver et al. (2024) documented a subsequent reversal, with below-knee amputations (BKA) rising to approximately 13 per 100,000 and above-knee amputations (AKA) to approximately 8 per 100,000 by 2021—a combined rate of approximately 21 per 100,000, and substantially higher than peer nations such as the UK and Netherlands. The Commonwealth Fund's *Mirror, Mirror* 2024 report ranked the US last overall among 10 high-income countries on health outcomes, though it should be noted that some health policy researchers have argued that this ranking's equity-weighted methodology structurally disadvantages the US relative to its clinical performance in certain domains (Papanicolas et al., 2018); the pattern of elevated amputation rates, however, is independently corroborated across multiple data sources. The fee-for-service reimbursement environment, which structures payment around procedural volume rather than longitudinal outcomes, has been identified as a contributing factor to this reversal, prompting the CMS policy goal of transitioning all Medicare beneficiaries to Value-Based Care arrangements by 2030 (CMS, 2025; CMS Innovation Center, 2022).

Global Themes

A pervasive finding across recent literature is that, irrespective of a health system's financial resources, formal physician education in wound pathophysiology remains fundamentally deficient (Gould & Herman, 2025). Currently, wound management is rarely taught as a cohesive, standalone clinical discipline; rather, it is heavily

Table 2: Metabolic Burden, Systemic Buffering Capacity, and Amputation Outcomes by Health Model

Health System Model	Metabolic 'input' (Obesity & Diabetes Burden)	Systemic 'Buffer' (Preventive Infrastucture)	Amputation Rate (per 100,000)
Beveridge (UK, Spain, NZ)	Moderate - High sugar/fat intake; managed via state-led obesity task forces.	Strong - Universal primary care acts as gatekeeper to catch early PAD	**LOW** **2.9 - 8.3 per 100k** ✓ **Controlled by standardization**
Bismarck (Germany, Japan, France)	Varied - Low in Japan; moderate in Germany; high smoking-related PAD	Maximal - World leading specialist density; rapid revascularization for elderly	**MODERATE** **4.3 - 8.6 per 100k** ✓ **Stable despite aging population**
NHI (Canada, Taiwan, S. Korea)	High / Rising - Significant obesity (Canada); rapid urbanization (Taiwan)	Efficient - Single-payer data enables predictive models to target high risk feet	**STABLE** **5.0 - 7.0 per 100k** ✓ **Balanced by cost-control pathways**
U.S. Mixed (Fragmented)	Critical - World-leading obesity & Type 2 Diabetes	Fragmented - High innovation, but 'amputation deserts' and fraud limit access	**HIGHEST** **12.0 - 40.0 per 100k** × **Driven by systemic misalignment**
Out-of-Pocket (Low-Income Nations)	Emerging - Double burden of malnutrition and rising urban obesity	Weak - Lack of infrastructure; PAD undiagnosed until limb necrotic	**SEVERE** **UP TO 24.4 ASYR** × **Highest disability burden**

Low amputation rate (well-buffered)
Stable amputation rate
High/Severe amputation rate
Strong systemic buffer
Weak/Fragmented buffer

fragmented across dermatology, surgical and primary care rotations (Reiter et al., 2025). Because traditional curricula often isolate the physical wound from the whole patient, emerging clinicians are systematically underprepared to manage the underlying metabolic and systemic drivers of non-healing wounds.

Integrated systems such as the Beveridge, Bismarck and National Health Insurance (NHI) models consistently maintain low to moderate amputation rates (ranging from 2.9 to 8.6 per 100,000) despite facing moderate, high, or rising metabolic burdens and aging populations. They achieve this stabilization through robust systemic buffers, including state-led preventive task forces, universal primary care gatekeeping, world-leading specialist density and predictive clinical pathways.

A fundamental determinant of a health-care system's efficacy is its underlying ontological approach to wound care. The paradigm through which a lower-extremity ulcer is perceived—either as a localized, topical lesion or as a manifestation of profound systemic pathology—constitutes a critical barrier to effective limb preservation. This ideological divide, long characterized by wound specialists as the "hole versus whole" perspective (Sussman & Bates-Jensen, 2012), underscores the dichotomy between procedurally driven sickness management and integrated, preventive health maintenance.

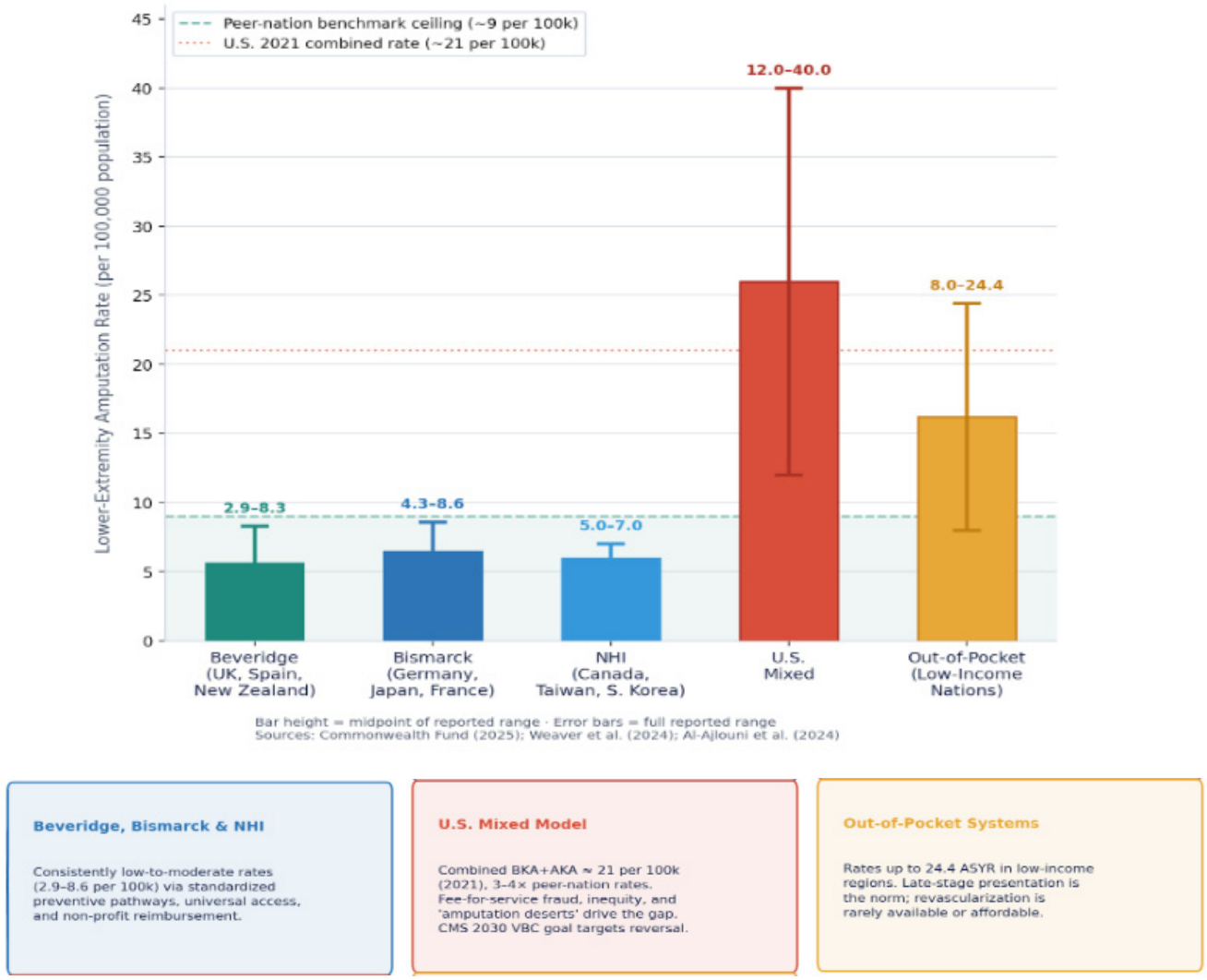
Regardless of the specific health-care delivery model, prevailing clinical and economic data consistently demonstrate that limb salvage represents a fundamentally superior long-term financial investment compared to amputation. Cost-effectiveness analyses of revascularization strategies for critical limb ischemia demonstrate that both endovascular and surgical approaches produce lower 10-year total costs than primary amputation while generating greater health benefits measured in years of ambulatory function and quality-adjusted life-years (Barshes et al., 2014). The NIH-funded Lower Extremity Assessment Project (LEAP)—the largest prospective multicentre study of limb-threatening injuries—projected lifetime health-care costs of $509,275 (all figures in USD) per amputee versus $163,282 for limb reconstruction, a difference exceeding three to one (MacKenzie et al., 2007). It should be noted that the LEAP cohort comprised primarily younger patients (mean age approximately 35 years) with traumatic lower-extremity injuries at Level I trauma centres; while derived from a trauma population rather than the older dysvascular or diabetic foot cohort that accounts for the majority of non-traumatic amputations. LEAP, nonetheless provides the most methodologically rigorous prospective lifetime cost estimate available in the peer-reviewed literature. Adjusted to current medical cost dollars using Bureau of Labor Statistics medical cost inflation (CPI for medical care services, 2007–2024; approximate multiplier 1.48), this per-patient lifetime burden well exceeds $700,000 (all figures in US) (MacKenzie et al., 2007). A national simulation model applied this per-patient estimate across the annual US lower-extremity amputation volume and estimated aggregate lifetime direct health-care costs at $46.7 billion, with a formal limb salvage program projected to reduce this burden by $15.2 to $38.5 billion depending on salvage rate assumptions (Tan et al., 2016; derived from a conference simulation model; peer-reviewed replication has not yet been published, and these projections should be interpreted accordingly).

A macro-level analysis of global amputation rates reveals a striking epidemiological paradox: both resource-constrained Out-of-Pocket systems and the exponentially high-expenditure United States Mixed model exhibit the highest global incidences of lower extremity limb loss, albeit driven by fundamentally divergent systemic mechanisms. The Beveridge, Bismarck and NHI Models demonstrate optimal preservation—maintaining major amputation rates of merely 5.6 to 6.5 per 100,000 population through standardized primary care gatekeeping, universal access to prophylactic podiatric screening and non-profit reimbursement structures. By contrast, US below-knee amputation (BKA) rates had risen to approximately 13 per 100,000 and above-knee amputation (AKA) rates to approximately 8 per 100,000 by 2021—a combined burden roughly three to four times greater than peer nations (Weaver et al., 2024). (See Tables 2 and 3.)

Table 3: Health System Expenditure, Chronic Disease Burden, and Amputation Outcomes

Health System Model	Health Spend (% of GDP)	Chronic Disease Burden	Amputation Rate (per 100,000)	Mirror, Mirror 2024 Rank
Beveridge (UK)	~10 - 12%	Moderate	**2.9 - 8.3**	**Top Tier (High Equity)**
Bismarck (Germany)	~11 - 13%	Moderate / High	**4.3 - 8.6**	**Top Tier (High Access)**
NHI (Canada)	~11 - 12%	High	**5.0 - 7.0**	**Mid Tier**
U.S. Mixed	17.3%	Critical	**12.0 - 40.0**	**Last (Worst Outcomes)**
Out-Of-Pocket	< 5%	Emerging	**Up to 24.4 (ASYR)**	**NA**

Graph 1: Lower-Extremity Amputation Rate by Global Health System Model



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Section III. The Middle East and North Africa (MENA) Region: A Landscape of Contrasts

No region in the world more starkly illustrates the relationship between political architecture, health system design and amputation outcomes than the Middle East and North Africa (MENA). Spanning 21 countries and over 600 million people, MENA is not a monolithic system but a deeply heterogeneous mosaic. Within its borders coexist petro-state tertiary care centres equipped with the latest endovascular technology, conflict zones where surgeons perform limb amputations without anesthesia and transitional hybrid systems navigating the tension between expanding coverage and entrenched structural fragmentation.

The metabolic burden confronting this region is arguably the highest on earth. According to the International Diabetes Federation, 73 million adults in the MENA region are currently living with diabetes (IDF Diabetes Atlas, 10th ed., 2021; updated to 85 million in IDF Diabetes Atlas, 11th ed., 2024)—a figure that represents the largest proportional share of any IDF region globally. More than one in five people in Africa and the Middle East combined are affected by diabetes, alongside foot ulcers or amputations—the highest burden of any world region (IDF Diabetes Atlas, 2021). The Global Burden of Disease dataset, analyzed across 21 MENA nations from 1990 to 2019, documents an overall annual increase of 1.39% in age-standardized LEA incidence rates (Al-Ajlouni et al., 2024).

The Gulf States: Advanced Capability, Structural Gaps

The high-income Gulf Cooperation Council (GCC) states—Saudi Arabia, the United Arab Emirates, Qatar, Kuwait, Bahrain and Oman—represent the most resource-advanced tier of MENA's health-care landscape. A 2025 Gulf Consensus document published by Wounds International formalized region-specific clinical guidelines advocating for annual diabetic foot screening, ankle-brachial pressure index (ABPI) assessment and standardized referral pathways for revascularization.

However, clinical sophistication at the tertiary level has not been matched by robust primary prevention infrastructure. A scoping review of diabetic foot disease management in GCC countries found that 72% of patients with diabetes in the UAE lack access to crucial foot care (Alessa et al., 2025). Furthermore, only Saudi Arabia among all 22 Arab nations has published national incidence studies on diabetic-related amputations; 17 countries report no prevalence data whatsoever. Without the data architecture to identify high-risk populations proactively, even well-resourced Gulf health systems default to treating late-stage disease rather than preventing it.

Conflict Zones: Traumatic Amputation As Health-care Systems Collapse

At the opposite pole of the MENA spectrum, conflict-affected nations present a profoundly different limb loss crisis—one driven primarily by traumatic injury and the wholesale destruction of health-care infrastructure. The GBD dataset documents that Syria, Yemen and Afghanistan registered the most dramatic increases in LEA rates across the entire MENA region between 1990

and 2019, with Syria recording a gross percentage increase of 330% in male LEA rates and 377.8% in female rates (Al-Ajlouni et al., 2024). In Yemen, 76% of all amputations over the 2016–2024 period were directly attributable to war-related injuries—predominantly affecting young male civilians with a mean age of 28 years (Hammad et al., 2025). By 2017, the Syrian Civil War had produced an estimated 86,000 amputations and 1.5 million permanent disabilities (WHO EMRO, 2025).

The ongoing conflict in Gaza has produced a particularly acute amputation crisis. Save the Children reported that more than 1,000 children underwent leg amputations in the first two months of conflict alone—a figure corroborated by field reports from UNICEF and the World Health Organization (Save the Children, 2024). Many of these procedures were performed without anesthesia due to critical supply shortages—representing the terminal endpoint of health-care system collapse.

Egypt: The Transitional Hybrid and Its Limb Preservation Paradox

Egypt occupies a unique and instructive position within MENA's health-care mosaic: it is a nation large enough—at over 100 million people—to constitute a health-care system unto itself, ambitious enough to have legislated universal coverage, and structurally complex enough that those ambitions remain partially unrealized. With a diabetes prevalence of 20.9% among adults, Egypt carries an enormous metabolic burden whose clinical consequences manifest disproportionately as diabetic foot disease, peripheral arterial disease (PAD) and ultimately lower-extremity amputation (IDF Diabetes Atlas, 2021).

A study from Alexandria University's Diabetic Foot Screening Clinic found that among 2,000 consecutive adult patients with diabetes, 4.4% had a documented history of non-traumatic amputation and 8.7% presented with active ulceration—reflecting a pattern of late-stage clinical presentation that is the hallmark of systems lacking effective primary prevention (El-Nahas et al., 2009); though derived from a single centre over a decade ago, this pattern is consistent with more recent observations of delayed presentation in Egyptian tertiary settings. Critically, one analysis found that treating a severe diabetic foot wound in Egypt may require up to 62.3 months of average salary—the highest financial burden of any country studied globally—rendering timely specialist care economically inaccessible for the majority of the population (Dhatariya & Abbas, 2025).

Egypt's Health-care System: Structure And The UHI Reform

For decades, Egypt's health-care system was characterized by four structural deficiencies: a fragmented regulatory and financing architecture, out-of-pocket expenditures comprising over 60% of current health expenditure, inadequate public funding at merely 1.5% of GDP, and a geographical imbalance in the distribution of skilled health-care workers. The Universal Health Insurance (UHI) Law of 2018 represents the most ambitious structural reform in the country's health-care history. The benefit package covers over 3,000 health services including surgical operations, prosthetic devices and complex diagnostic imaging (iPMI Global, 2024). Full national rollout is planned across six phases over 15 years, with completion anticipated by 2032–2033.

Early outcome data on the UHI are cautiously encouraging. A cross-sectional study conducted in 2021–2022 found that UHI beneficiaries reported an 80% greater likelihood of perceiving good overall accessibility. However, the same study found no statistically significant improvement in perceived quality of care between the two groups—a critical distinction. Expanded access to a fragmented, inadequately resourced system does not automatically translate into improved clinical outcomes (Hammad et al., 2025).

The Limb Preservation Gap: Late Presentation And The Default To Amputation

Despite the structural promise of the UHI reform, the clinical reality for Egypt's diabetic foot patients reflects entrenched systemic barriers that legislative change has not yet resolved.

The most consequential of these is the pattern of late-stage clinical presentation. By the time a patient with a diabetic foot ulcer presents to a university hospital, the wound has frequently progressed to deep tissue infection, osteomyelitis, or critical limb ischemia—stages at which revascularization is technically complex, outcomes are uncertain and major amputation often becomes the most expedient available intervention.

This dynamic is reinforced by the absence of standardized multidisciplinary limb salvage programs in Egyptian public hospitals. Referral pathways remain largely ad hoc, specialist density outside major academic centres is low, and outcome-based reimbursement mechanisms are absent from the current UHI framework. In this environment, major amputation functions as a rapid, definitive solution to a complex problem that the surrounding system is not yet structurally equipped to solve through limb preservation. It is, in the language of this analysis, an institutional default rather than a clinical last resort.

Emerging Pathways And The Road Forward

Despite these challenges, there are meaningful emerging signals of reform in both Egypt and the broader MENA region. Egypt's UHI system, when fully implemented, will represent the largest expansion of health-care access in the nation's modern history and will create the financing architecture necessary—if not yet sufficient—to support systematic limb salvage programs. The critical next step is embedding outcome-based reimbursement within the UHI framework: ensuring that providers are financially rewarded for healed wounds and preserved limbs rather than merely for surgical throughput.

Across the broader MENA region, growing recognition of unmet rehabilitation needs aligns with the WHO's Rehabilitation 2030 initiative, which has documented that in many low- and middle-income countries more than 50% of people do not receive the rehabilitation services they require (World Health Organization, 2017). The MENA region, taken as a whole, thus embodies the full spectrum of amputation causation: from the metabolic-preventable to the trauma-inevitable, from the resource-constrained to the capacity-constrained, from the legislatively ambitious to the structurally collapsed.

Section IV. The United States

Structural and Behavioural Drivers Of The US Amputation Crisis

Lower-extremity amputation trends in the United States reflect a trajectory of greater complexity than aggregate comparisons with peer nations suggest. Longitudinal Medicare data analyzed by Goodney et al. (2013) documented substantial declines in major amputation rates from the early 1990s through the early 2010s, concurrent with increasing rates of both surgical bypass and percutaneous endovascular interventions—evidence that the US health-care system demonstrated measurable capacity for improvement when revascularization access expanded. The subsequent reversal documented by Weaver et al. (2024), with combined below- and above-knee amputation rates reaching approximately 21 per 100,000 by 2021, therefore warrants analysis not as evidence of static failure but as a system that achieved gains and then lost them—raising the clinically and policy-relevant question of which structural conditions enabled the earlier decline and which changes since eroded it. At the clinical level, the primary physiological substrate for non-traumatic lower-extremity amputation is the convergence of diabetes mellitus and peripheral artery disease (PAD): with over 38 million Americans currently managing diabetes (CDC, 2023), the at-risk population is both large and growing, creating a metabolic burden that places particular demands on preventive and vascular care infrastructure.

Social Determinants of Health (SDOH) independently influence amputation risk in ways that clinical intervention alone cannot fully offset. County-level analyses demonstrate that a $10,000 decrease in median household income correlates with a 4.4% increase in major amputation rates, establishing a precise socioeconomic gradient that operates independently of baseline metabolic burden (Hicks et al., 2023). Emerging

pharmacological evidence also suggests differential protective effects by drug class: a large Danish target trial emulation found that SGLT-2 inhibitor users had a modestly lower 6-year risk of diabetic foot disease compared with GLP-1 receptor agonist users, driven primarily by reduced peripheral neuropathy (Kristensen et al., 2026), indicating that medication access inequities compound the SDOH-driven disparity in amputation risk. This socioeconomic gradient is further potentiated by the physiological mechanism of allostatic load—the cumulative biological cost of chronic psychosocial stress, which drives sustained elevation of cortisol and inflammatory markers, accelerating endothelial dysfunction and atherosclerotic progression in chronically resource-constrained populations (McEwen, 1998).

Fraud And Abuse: The Systemic Economic Misalignment

The fee-for-service (FFS) reimbursement architecture creates structural incentives that, in the wound care context, have been documented to reward procedural volume over clinical outcomes. Recent evaluations by the Department of Health and Human Services Office of Inspector General (HHS OIG) found that Medicare Part B spending on skin substitutes in non-institutional settings escalated by over 640% within a two-year period, surpassing $10 billion annually by the end of 2024—a pattern the OIG characterized as reflecting a combination of fraud, waste, abuse and misaligned pricing incentives warranting urgent policy reform (HHS OIG, 2025). The enforcement record illustrates the downstream consequences of these incentive structures: federal prosecution of one medical conglomerate identified a $1.2 billion scheme involving medically unnecessary amniotic allografts administered to elderly and hospice patients. The owners—sentenced on October 7 and October 10, 2025, to 15.5 and 14 years respectively—were ordered to pay criminal restitution exceeding $1.2 billion and approximately $410 million in forfeitures; on December 12, 2025, they additionally agreed to pay $309 million to resolve civil liability under the False Claims Act (DOJ, 2025). When reimbursement structures reward the repeated application of high-cost biological products rather than coordinated chronic disease management, the clinical environment shifts away from the multidisciplinary, systems-level approach that the evidence base consistently identifies as necessary to prevent amputation.

The 2030 Transition: Value-Based Care And Innovation

The CMS Value-Based Care (VBC) goal of transitioning all Medicare beneficiaries to accountable care arrangements by 2030—a policy target rather than a legislated mandate—represents a structural response to the documented misalignment between reimbursement incentives and clinical outcomes under fee-for-service payment (CMS, 2025; CMS Innovation Center, 2022). The core mechanism is a shift from payment for procedural volume toward payment contingent on long-term preventive outcomes, creating a financial architecture in which preventing amputation becomes economically rational for the accountable care organization (CMS, 2024). This structural realignment is being accompanied by an emerging layer of digital health and artificial intelligence tools that operationalize predictive risk stratification at the point of care. Evidence supporting remote patient monitoring applications in high-risk diabetic populations—including sensor-based plantar pressure and temperature monitoring systems—suggests potential for earlier detection of impending ulceration, though the evidence base for population-level amputation reduction remains an active area of investigation (Bus et al., 2020; Najafi et al., 2017).

The Structural Threat: Why Value-Based Care Alone Is Insufficient

The United States' transition to Value-Based Care confronts a foundational paradox: VBC rewards outcomes that its underlying workforce and information architecture are not yet consistently equipped to deliver. Chronic wound management

sits at the precise intersection of this gap. Despite costing Medicare an estimated $22.5 billion annually and affecting approximately 10.5 million Medicare beneficiaries, chronic wounds remain conspicuously absent from the CMS quality measure portfolio—none of the episode-based measures currently proposed under MACRA encompasses wound care (Nussbaum et al., 2018). When a payment system does not measure wound healing, it cannot reward it—and the fragmented specialist referral patterns, delayed advanced therapy adoption and inequitable geographic distribution of wound expertise remain structurally unchallenged.

The Educational And Credentialing Imperative

The clinical evidence establishing the superiority of integrated, team-based wound care is robust and consistent: multidisciplinary diabetic foot teams reduce major amputations by 48% to 70% in controlled settings (Santema et al., 2021). Yet the United States currently lacks a standardized, nationally required competency framework that ensures every clinician who encounters a chronic wound possesses a baseline of integrated wound assessment knowledge anchored in chronic disease context.

The solution therefore requires a parallel architecture alongside VBC: mandatory interprofessional wound care competency education embedded within existing health professional programs, site-of-care credentialing requirements for facilities managing wound-bearing populations under accountable care contracts, and evidence-based clinical pathways that are actively integrated into Electronic Medical Record (EMR) systems via clinical decision support tools. Machine learning models trained on wound characteristics and comorbidity profiles have demonstrated AUC values of 0.82–0.90 for predicting major amputation risk at the point of hospital admission (Oei et al., 2025)—precisely the inflection point at which early intervention remains mechanistically and economically viable.

The Wound As A Turning Point: A Call To Reframe

The United States is a nation of profound demographic and socioeconomic complexity. What these populations share, however, is not a common risk factor profile but a common system failure: the absence of an integrated approach that treats the chronic wound not as an isolated dermatological event to be dressed and rebilled, but as the visible signal of chronic disease that has not been adequately managed at every prior inflection point in the care cascade.

A healed wound is not merely a dermatological success. It represents demonstrated glycemic control, resolved vascular ischemia, managed infection, adequate nutrition, adherent offloading, and sustained patient engagement with a coordinated care team. If the wound is the endpoint of chronic disease management failure, then the healed wound and the amputation-free patient is the most concrete and measurable expression of chronic disease management success. The wound outcome is not merely a quality indicator for wound care; it is a quality indicator for the entire system that produced or prevented it (Nussbaum et al., 2018; Sen, 2025; Hicks et al., 2023).

The pathway forward is not VBC alone—nor education alone, nor AI alone—but their deliberate co-design. A VBC framework that includes wound-specific quality measures (healed wound rate, amputation-free days, time to advanced therapy) creates the financial architecture. Mandatory interprofessional wound care competency builds the human architecture. AI-enabled EMR decision support builds the informational architecture. And the unifying clinical principle—that the wound is part of the human, that the human lives within a chronic disease trajectory—provides the philosophical architecture that makes the others coherent.

Section V. Conclusion And Call To Action

Across the four global health system models examined in this analysis—Beveridge, Bismarck, National Health Insurance and Out-of-Pocket—and across the highly contrasting regional paradigms of MENA and the United States, one principle has emerged with unambiguous clarity: the amputation rate is not a random clinical outcome. It is a structural verdict. It reflects, with devastating precision, whether a health system has chosen to invest in prevention or wait for crisis, to coordinate care or fragment it, to reward healing or incentivize procedure.

The evidence reviewed in this analysis converges on several universal findings. First, metabolic burden alone does not determine amputation rates; the Beveridge and Bismarck models demonstrate that populations with moderate to high diabetes prevalence and aging demographics can maintain low LEA rates through standardized gatekeeping, universal access, and reimbursement structures that prioritize preventive outcomes. Second, systemic fragmentation is the most powerful predictor of elevated amputation incidence—whether that fragmentation manifests as the fee-for-service incentive misalignment of the United States, the referral pathway breakdown of Egypt's transitional system, or the infrastructure collapse of conflict-affected MENA nations. Third, the financial case for limb preservation is incontrovertible: the NIH-funded Lower Extremity Assessment Project established projected lifetime health-care costs of $509,275 per amputee versus $163,282 for reconstruction—a difference exceeding three to one (MacKenzie et al., 2007). This estimate derives from a trauma cohort of primarily younger patients (mean age approximately 35 years) at Level I trauma centres, rather than the older dysvascular or diabetic foot population that accounts for the majority of non-traumatic amputations; direct extrapolation to diabetic foot cohorts therefore requires interpretive caution. Nonetheless, adjusted to current medical cost dollars using Bureau of Labor Statistics CPI for medical care services (2007–2024; approximate multiplier 1.48), this per-patient lifetime burden well exceeds $700,000—making investment in early revascularization and multidisciplinary wound care not only clinically superior but economically rational by any defensible measure.

Crucially, the evidence confirms that wound-level intervention in the absence of systemic chronic disease management does not prevent amputation. A systematic review and meta-analysis of 57 studies found that structured multidisciplinary teams—integrating glycemic control, vascular assessment, infection management and wound care within a coordinated pathway—reduced major lower-extremity amputation risk by 48% relative to fragmented care (Santema et al., 2021; Musuuza et al., 2020). The organizational architecture of the health system, therefore, is not a background condition for wound outcomes—it is the primary determinant of them.

Looking forward, the global inflection points identified in this analysis offer genuine cause for cautious optimism. The US CMS goal of transitioning all Medicare beneficiaries to Value-Based Care arrangements by 2030 represents the most significant structural recalibration of the world's largest health-care economy toward prevention and healing outcomes. The core principle underlying this shift—that reimbursement structures should reward healed wounds and preserved limbs rather than procedural volume—has potential relevance beyond the US context. However, the structural, fiscal and institutional conditions that shape how outcome-based payment functions in a fragmented multi-payer environment differ substantially from those of Egypt's nascent universal insurance framework, the Gulf states' predominantly tax-financed tertiary systems, or the single-payer architectures of the Beveridge and NHI models. Transferability of specific VBC mechanisms therefore cannot be assumed; each system would require careful contextual evaluation to identify which elements are adaptable and which require fundamental redesign to fit local financing and governance realities. Egypt's Universal Health Insurance system, despite its implementation challenges, establishes the financing and institutional foundation upon which outcome-

oriented limb salvage pathways can eventually be built. Across the Gulf states, the formalization of regional diabetic foot guidelines signals a maturation from reactive tertiary care toward proactive population health management.

The call to action that emerges from this analysis is addressed to policymakers, clinicians, educators and health system architects worldwide. It demands, first, that physician education systems globally be reformed to treat chronic wound management, not as a peripheral clinical footnote, but as a core competency.

A note on comparability and generalizability:
The health systems examined in this analysis—spanning Beveridge, Bismarck, National Health Insurance and Out-of-Pocket financing models, and encompassing the highly divergent regional contexts of the United States and MENA—differ profoundly in their structural, fiscal, cultural and institutional foundations. Meaningful differences exist not only between national systems but frequently within them, across regions, payers and populations. As a result, direct, equitable comparison across these systems is inherently limited, and the generalizability of any single system's findings or interventions to another cannot be assumed. What this analysis does offer, however, is an identification of recurring themes—patterns that appear across multiple systems and contexts—that may represent causal drivers of amputation outcomes, meaningful correlates, or both. Whether causative or correlative, these shared patterns are noteworthy and merit rigorous scrutiny. Equally, each system examined demonstrates notable areas of measurable success in limb preservation that are themselves worthy of careful study, with the aim of identifying which elements may be adaptable and expandable within different systemic contexts. Most fundamentally, amputation is not a national or single-system problem. It is a global one. A cross-system, global-level analysis—however imperfect in its comparability—enables a breadth of policy discussion that no single-country examination can provide, and it is precisely this broader lens that creates space for more comprehensive, structurally informed advocacy for change.

It demands that health systems at every income level establish national diabetes registries and amputation surveillance databases, because what cannot be measured cannot be reduced. It demands that reimbursement architectures be restructured to reward healing velocity rather than procedural volume. And it demands that the amputation rate be formally adopted as a primary benchmark of health system performance. For those systems that have already achieved low amputation rates—the Beveridge, Bismarck, and NHI models examined here—the mandate extends further: to formalize outcome data sharing, publish transferable pathway models and engage in structured technical assistance with transitional and resource-constrained systems. High performance creates an obligation of knowledge export, not merely a benchmark for others to admire.

The legitimacy of amputation rate as a systems-level performance metric deserves direct defense. A parallel from within health care is instructive. Maternal mortality rate is accepted without controversy as one of the most powerful global benchmarks of health system performance—employed by the World Health Organization, the World Bank and every major global health institution as a sentinel indicator of whether upstream systems of access, prevention and coordinated care are functioning. No serious health policy scholar argues that maternal mortality rate is an invalid metric because most pregnancies do not end in maternal death, or because the structural differences between health systems make cross-national comparison imperfect. The metric is accepted precisely because it is rare, irreversible, and preventable—and because its rate, and the variation of that rate across systems and populations, reveals the cumulative performance of everything upstream: prenatal care access, skilled birth attendance, post-partum monitoring and the equity with which those resources are distributed. Amputation rate occupies an identical epistemological position. It is rare. It is irreversible. It is, in the overwhelming majority of cases, preventable. And its rate—and the profound variation of that rate across health systems,

income strata, and racial and geographic subpopulations—reflects with equal precision the cumulative performance of upstream systems: glycemic control access, primary care gatekeeping, vascular referral pathways, multidisciplinary wound care infrastructure and the equity with which each of those is distributed. To accept maternal mortality as a valid systems benchmark while declining to extend the same standing to amputation rate is not a methodological position—it is an oversight, and one this field can no longer afford.

Limb preservation is, at its core, a statement of values. It declares that a patient's mobility, independence and dignity are worth the sustained institutional investment required to protect them. Every health system that reduces its amputation rate has chosen, implicitly or explicitly, to prioritize human wholeness over procedural convenience. The aspiration of this analysis is that its findings contribute meaningfully to a world in which that choice becomes universal—and in which the loss of a limb to a preventable cause becomes, truly, the rare exception rather than the default.

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