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Vascular Surgery in Low-Income and Middle-Income Countries: A State-of-the-Art Review

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Background: Cardiovascular disease (CVD) represents 32% of all global deaths. Studies have shown an increase in CVD prevalence and mortality with the most substantial increase in low-income and middle-income countries (LMICs). Within LMICs, we sought to 1) measure the burden of CVD with respect to aortic aneurysm (AA), ischemic stroke (IS), and peripheral arterial disease (PAD); 2) quantify surgical access to vascular surgery services; and 3) identify challenges and solutions to addressing disparities.

Methods: The Institute for Health Metrics and Evaluation Global Burden of Disease Results Tool was used to assess the global burden of CVD (AA, PAD, IS). Population data were extracted from the World Bank & Workforce data. A literature review was completed through PubMed.

Results: The number of deaths attributable to AA, PAD, and IS in LMICs increased by up to 102% between 1990 and 2019. Disability-adjusted life-years (DALYs) lost to AA, PAD, and IS in LMICs also increased by up to 67%. High-income countries (HIC) had a less considerable increase in deaths and DALYs during this time period. There are 101 and 72.7 vascular surgeons per 10 million people in the United States and United Kingdom, respectively. LMICs, such as Morocco, Iran, and South Africa have 10 times less this number. Ethiopia has 0.25 vascular surgeons per 10 million people, 400 times less than the United States. Interventions addressing these global disparities should address infrastructure and financing, data collection and sharing, patient knowledge and beliefs, and workforce development.

Conclusions: Extreme regional discrepancies are evidence at a global scale. Identifying mechanisms to expand the vascular surgical workforce to meet the increasing need for vascular surgical access is imminent.

INTRODUCTION

Vascular surgery, whose practitioners are known as the firefighters of the operating room,[1] has become increasingly complex with the endovascular revolution and expensive with the introduction of custom devices. While the practice of vascular surgery in the global north continues to advance—integrating technological and pharmaceutical innovations on a greater scale,[2–4] demand for vascular surgeons in the global south remains partly met by physicians specialized in disciplines other than vascular surgery

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or unmet altogether.[5,6] An analysis of the World Bank and World Health Organization (WHO) population and workforce data revealed a profound dearth of surgeons serving populations in Africa, Southeast Asia, the Eastern Mediterranean region, as well as the Western Pacific regions.[7] Each of these regions was found to have less than 3 vascular surgeons per 10 million people; at least 5 times less than the number of vascular surgeons per 10 million people in the Americas and Europe.[7]

While this chasm in supply continues to widen, demand continues to rise. Peripheral arterial disease (PAD), and other conditions that vascular surgeons are uniquely equipped to treat (e.g., carotid and aortic disease), continue to increase globally. However, this increase is uneven, with low-income and middle-income countries (LMICs) disproportionately affected. Previous studies have shown LMICs to be experiencing a greater increase in prevalence of PAD, aortic aneurysm (AA), and ischemic stroke (IS) compared to high-income countries (HIC).[8–10] Prevalence of PAD has increased by 29% in LMICs compared to 13% in HIC over the same time period.[8] AA and IS have even declined in HIC while simultaneously increasing dramatically in LMICs.[9,10] Though advances have been made in reducing mortality caused by cardiovascular disease (CVD), this reduction is limited to HIC and some middle income countries; the remaining LMICs seeing no change or, in some cases, an increase in mortality.[11,12] It is evident that the global need for vascular surgeons has not been adequately met despite the World Health Assembly's adoption of WHA68.15 in 2015, designating access to surgical care a component of universal health coverage.[13]

In light of these trends, it is imperative to quantify both the global burden of vascular disease as well as access to vascular surgeons in LMICs to propose and implement appropriate solutions to any identified disparities. In this study, we sought to 1) measure the burden of CVD with respect to AA, IS and PAD; 2) quantify surgical access to vascular surgery services; and (3) identify challenges and solutions to addressing these disparities.

METHODS

Assessing Global Burden of Disease

The Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease Results Tool[14] was utilized to assess the global burden of 3 cardiovascular diseases: AA, IS, and PAD. These diseases served as a proxy for measurements regarding vascular disease. The IHME utilizes secondary data collected by thousands of scientists, government officials, and medical professionals as well as primary data collected in a 6-step process.[15] It is a trusted resource, previously utilized by dozens of studies.[16] The global burden of disease was assessed in terms of disability adjusted life-years (DALYs) and deaths. DALYs are a calculation of the years of healthy life lost due to premature mortality or disability. One DALY is equivalent to 1 year of healthy life lost. The mortality and morbidity of these cardiovascular diseases is summarized in Table I. Also included in Table I are communicable and noncommunicable diseases often prioritized in global health discourse and action including road injuries, tuberculosis, malaria, and HIV/AIDS.

Population data from 2019 were extracted from the World Bank.[17] Published literature, the Society for Vascular Surgery,[18] and the Cardiothoracic Surgery Network[19] database were accessed to extract the number of vascular surgeons. These data were utilized to calculate the number of vascular surgeons per 10 million people.

Literature Review

A thorough literature review was conducted by searching the PubMed database. Combinations of keywords relating to vascular surgery, global health, and low-income and middle-income countries were utilized to compile relevant published literature. Identified publications were then categorized according to their main subject under the following headings: global initiatives, delivery of care, infrastructure and financing, workforce development, and data collection and sharing.

RESULTS

Global Burden of Disease

Noncommunicable diseases account for 41% of premature deaths globally, with 86% of these deaths occurring in LMICs.[20] Moreover, cardiovascular diseases, many of which can be intervened upon by vascular surgeons, remain a leading cause of death globally, accounting for as much as one-third of global deaths.[12] Data collected in 2019 by the IHME were utilized to quantify the global burden of disease with regards to aortic aneurysm, IS, and PAD. These diseases served as a rough estimation of vascular disease burden.

Aortic aneurysms were found to account for 0.3% of global deaths and 0.1% of global DALYs. IS and PAD accounted for 5.8% and 0.1% of deaths and 2.5% and 0.1% of DALYs, respectively. Together, these 3 diseases outweigh the proportion

Table I. Global burden of disease in 2019

Cause	Deaths		Disability adjusted life-years	
	Number	Proportion of total (%)	Number	Proportion of total (%)
All causes	56,526,959	100	2,538,020,070	100
Aortic Aneurysms	172,427	0.31	3,322,343	0.13
Ischemic Stroke	3,293,397	5.83	63,478,271	2.50
Peripheral arterial disease	74,062	0.13	1,536,380	0.06

of deaths and DALYs due to HIV/AIDS and malaria, both of which make up a large percentage of ongoing global health efforts.[21] These findings are summarized in Table I.

The global burden of disease was further broken down according to World Bank-defined income levels. In upper middle-income countries, AA, IS, and PAD were the cause of 9.1% of deaths and 4.6% of DALYs. In lower middle-income countries, these 3 diseases accounted for 4.3% of deaths and 1.7% of DALYs. In low-income countries, AA, IS, and PAD accounted for 2.2% of deaths and 0.8% of DALYs. These findings are summarized in Tables II—IV. Finally, AA, IS, and PAD were the cause of 6.6% of deaths and 3.1% of DALYs in high-income countries. As such, the burden of disease due to these diseases is far greater in LMICs when compared to HICs, with the greatest burden found in upper-middle—income countries. A comparison of the burden of disease due to AA, IS, and PAD in terms of death or DALYs per 10,000 population in upper-middle, lower-middle, and low-income countries is found in Figures 1 and 2, with a statistical analysis of these differences found in Table V.

Trends in the global burden of disease attributable to IS, AA, and PAD between 1990 and 2019 were also analyzed using the number of deaths and DALYs per 100,000 people. During this time period, the rate of DALYs due to IS decreased by 31% in HIC. This is in contrast to the 39% and 21% increase seen in upper middle and lower middle-income countries, respectively. The rate of deaths due to IS in low-income countries remained stable. Figure 3 shows these findings. With regards to deaths attributable to IS, there was a 28% decrease in high-income countries from 1990 to 2019. Conversely, deaths attributable to IS increased by 49% and 27% in upper-middle and lower-middle—income countries, respectively. Low-income countries remained stable. These findings are illustrated in Figure 4.

The number of deaths per 100,000 people due to AA from 1990 to 2019 increased by 100% and 60% in-upper middle and lower income countries, respectively, while increasing by 16% in high-income countries. The rate of deaths due to AAs decreased by 20% in low-income countries. These findings are summarized in Figure 5. Similar trends were found when considering the rate of DALYs attributable to AA. Upper-middle and lower-middle—income countries saw a 63% and 47% increase, respectively. High-income countries remained stable while low-income countries saw a modest decrease. Figure 6 shows these findings.

Finally, the rates of deaths and DALYs due to PAD were analyzed. The rate of deaths due to PAD increased by 102% and 98% from 1990 to 2019 in upper middle and high-income countries, respectively. Lower middle income countries saw an increase of 60% while low-income countries had an increase of 28%. In terms of the rate of DALYs attributable to PAD, a 44% increase was noted in high-income countries. In upper middle and lower middle income countries, this rate increased by 67% and 60%, respectively. Low-income countries had a 14% increase in the rate of DALYs due to PAD. Findings regarding deaths and DALYs attributable to PAD are summarized in Figures 7 and 8. Previous studies utilizing similar data from the IHME Global Burden of Disease Results Tool affirm an increase in PAD disease burden across most sociodemographic index (SDI) or income levels and predict a continued increase through 2030, with the greatest rate of increase seen in low SDI regions.[22,23]

Global Access to Vascular Surgery

The second objective of this endeavor was to quantify global access to vascular surgery services. This access was quantified as the number of vascular surgeons per 10 million people. In the United States, there are approximately 101 vascular surgeons per 10 million people. The number in the United Kingdom is, similarly, 72.7 per 10 million people. This is in stark difference to the access to vascular surgery services found in LMICs.

Table II. Burden of disease in upper-middle–income countries

Cause	Deaths		Disability adjusted life-years	
	Number	Proportion of total (%)	Number	Proportion of total (%)
All causes	19,497,458	100	752,459,847	100
Aortic Aneurysms	54,500	0.28	1,177,024	0.16
Ischemic Stroke	1,708,178	8.76	33,246,046	4.43
Peripheral arterial disease	19,957	0.10	526,001	0.07

Table III. Burden of disease in lower-middle–income countries

Cause	Deaths		Disability adjusted life-years	
	Number	Proportion of total (%)	Number	Proportion of total (%)
All causes	21,216,710	100	1,104,515,873	100
Aortic Aneurysms	34,943	0.16	794,568	0.07
Ischemic Stroke	888,453	4.19	18,608,312	1.69
Peripheral arterial disease	7,765	0.04	246,933	0.02

In Morocco and South Africa, there are 13.2[24] and 10.8[25] vascular surgeons per 10 million, respectively—a 10th of the access found in the United States. In Iran, this number further decreases to 10.[26] Finally, in Ethiopia, access to vascular surgery services is most restricted with 0.25 vascular surgeons per 10 million people,[27] 400 times less than in the United States. Though access to vascular surgery services can and should be increased globally as evident by work by the Society of Vascular Surgery (SVS) and Association of Program Directors in Vascular Surgery (APDVS), the vast difference between HICs and LMICs suggests a dire need to address this disparity in areas with the least access.

DISCUSSION

Challenges and Solutions to Addressing Disparities

Vascular surgery, despite being a relatively new specialty, has enjoyed progressive worldwide acceptance and exponential growth. Access to vascular surgeon services, however, remains limited. A thorough PubMed literature review has allowed identification of several barriers to increasing this access. These barriers present a valuable opportunity for intervention. They have been organized thematically, according to the following themes: infrastructure and financing, data collection and sharing, knowledge and beliefs, and workforce development.

Infrastructure and Financing

A primary barrier to increasing access to surgery services in LMICs is the lack of suitable infrastructure. More specifically, a lack of sufficient operating theaters, frequent power outages, and inadequate surgical equipment and supplies[28,29] prevent widespread access to surgical services. Despite being assessed with regards to surgical access in general, these limitations extend to vascular surgery.[30–32] Addressing these barriers is further hindered due to a lack of financing, with cost often cited as a factor of this limitation[33,34] Improving access to vascular surgery in LMICs can, in part, be accomplished by increasing surgical infrastructure through increased and sustainable financing. Providing vascular care, even in centers with access to operating theaters, is challenging due to the lack of access to computed tomography angiography, angiography suit, reliable electricity, and endovascular devices.[33,35,36]

When surgical services are available, however, a barrage of patient-centered cost and infrastructure barriers still remain. Previous studies have shown that direct costs associated with surgical intervention have prevented patients from utilizing these services.[29,37–40] Patients, despite recognizing the need for surgical care, are unable to make use of these services due to an inability to afford them. The indirect costs associated with receiving surgery, such as loss of income and permanent disability, also serve as a hindrance.[41–43] Moreover, patients report limitations to transportation due to improper or

Table IV. Burden of disease in low-income countries

Cause	Deaths		Disability adjusted life-years	
	Number	Proportion of total (%)	Number	Proportion of total (%)
All causes	4,941,550	100	322,758,976	100
Aortic Aneurysms	5,281	0.11	131,777	0.04
Ischemic Stroke	105,225	2.13	2,455,709	0.76
Peripheral arterial disease	2,229	0.05	57,467	0.02

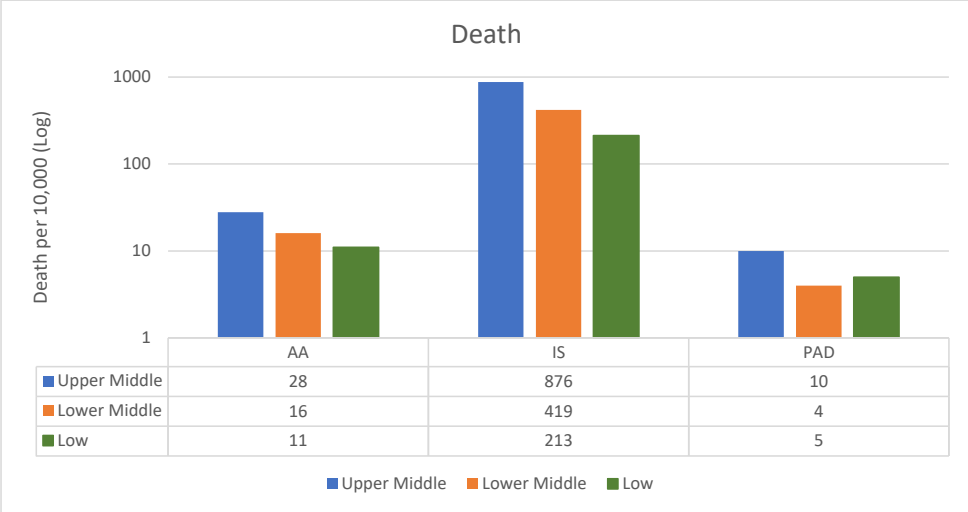

Fig. 1. Comparison of the rate of deaths per 10,000 people in upper-middle, lower-middle, and low-income countries.

insufficient transport and long distances as reasons for not seeking immediate surgical care.[44,45] Any interventions aimed at increasing accessibility of vascular surgery services should be implemented with the goal of reducing costs and increasing accessibility to patients in mind. This ensures that the availability of services is not hindered by the lack of affordability or vice versa, rendering them useless despite their presence. The utilization of endovascular technology is associated with further costs and the policy of insurance companies regarding the coverage of these new technologies differ in LMICs.

Data Collection and Sharing

A sense of global camaraderie has long existed in vascular surgery,[46] with international collaboration encouraged and promoted.[46–48] Vascular registries, for example, have served as an important opportunity to share data and improve practices. These registries have become increasingly collaborative, with initiatives such as the World Federation of Vascular Societies and the International Consortium of Vascular Registries (ICVR) fostering greater global integration and information sharing.[46,49] LMICs, however, have largely been excluded from these efforts. In the ICVR, all 15 member organizations are HICs, with no LMIC representation. The World Federation of Vascular Societies has marginally better representation, with 3 LMICs represented among dozens of HICs.

This lack of representation is likely, in part, due to the lack of systematic data collection in LMICs. Collection of information at the scale seen in HIC requires a development of infrastructure including greater access to reliable internet and technology, sufficient personnel to input this data, and globally agreed-upon standards for care. Efforts focused on increasing data availability in LMICs should target these aspects, prioritizing sustainable increases in capacity and capability. One successful example of nationwide data collection in an LMIC is the Vascular Society of South Africa (VASSA). With its targeted mandate, VASSA has been able to take

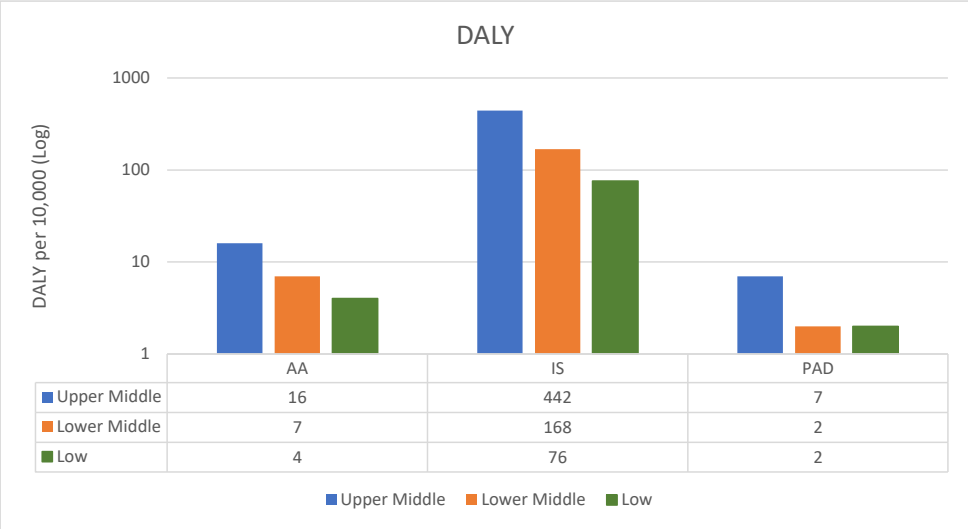

Fig. 2. Comparison of the rate of DALY per 10,000 people in upper-middle, lower-middle, and low-income countries.

Table V. Statistical analysis comparing death and DALY in upper middle income, lower middle income, and lower income countries (Chi-square)

Cause	Death	DALY
Aortic Aneurysms	<0.001	<0.001
Ischemic Stroke	<0.001	<0.001
Peripheral Arterial Disease	<0.001	<0.001

DALY, disability adjusted life years.

into consideration the unique aspects of South Africa's vascular pathologies such as the impact of HIV.[25] Moreover, this society has enabled the promotion and advancement of research in vascular surgery, increased knowledge in vascular disease, and served as a representative on the global stage for increased vascular surgery services in LMICs.[25,46] VASSA is a tangible example of the feasibility and subsequent success of implementation of vascular registries and societies in LMICs. This, in turn, fosters greater international collaboration.

Knowledge and Beliefs

Delivery of care to patients in LMICs is hindered by factors beyond infrastructure and costs. Patient-centered and culture-specific elements also play a significant role in creating barriers to effective delivery of surgical care. In Nepal, for example, literacy has been shown to be a significant barrier to care.[50] Other factors include fear of surgery, minimal community health education, and mistrust of

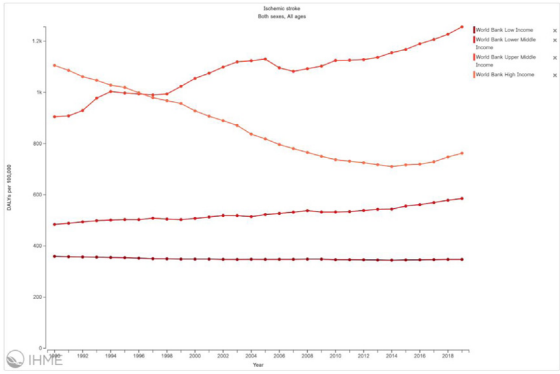

Fig. 3. DALY per 100,000 people due to ischemic stroke between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

the healthcare system.[37,50–52] Interventions targeting these barriers should include community participation. Incorporation of knowledge and beliefs held by community members will allow for the development of interventions that are better suited for the community they seek to benefit as well as an increased likelihood of acceptance by the population. With regards to vascular surgery, increasing patient knowledge of vascular diseases, such as PAD, and their manifestations may allow for earlier intervention and improved outcomes.[53,54]

Workforce Development

A final category of barriers to care is the development of a suitable vascular surgeon workforce.

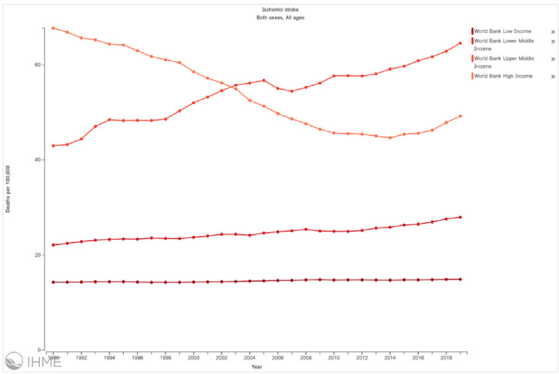

Fig. 4. Deaths per 100,000 people due to ischemic stroke between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

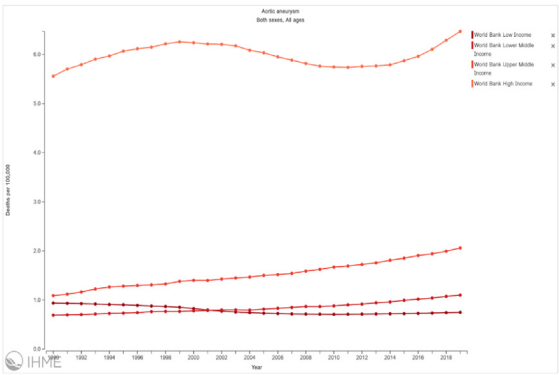

Fig. 5. Deaths per 100,000 peopl due to peripheral arterial disease between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

Training in vascular surgery, despite increasingly being recognized as a monospecialty, remains unstandardized. The structure of resident training differs both across and within countries,[55,56] preventing the formation of a globalized standard of training. Many Sub-Saharan nations do not recognize vascular surgery as its own specialty, but rather as a subspecialty to general surgery. This limits the scope of practice of vascular surgeons and hinders advancement in technique and technology.[5] Carving out a defined scope of practice for vascular surgeons, reflected by an autonomous training program, may allow for more rapid growth of the profession and foster greater advancement in skills, thereby meeting the demand for vascular surgeons more quickly and precisely.[5] Implementation of integrated vascular surgery residency programs in LMICs which have traditional fellowship programs is another way to increase the number of vascular surgeons. Many surgeons are not interested in vascular surgery fellowship programs due to the lengthy duration of training (4–5 years of general surgery residency + 2–3 years of vascular surgery fellowship).[57]

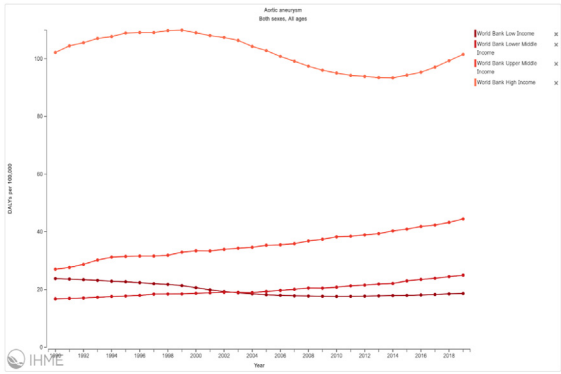

Fig. 6. DALY per 100,000 people due to peripheral arterial disease between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

Though the lack of standardization is not unique to LMICs, the vascular surgeon training programs in LMICs face distinct limitations. A unique disease burden intersecting with vascular disease in these countries, such as HIV and Buerger's Disease, necessitate specific training to best intervene upon these diseases.[5,6] Moreover, the limitations to surgical care access relating to infrastructure, cost, and delivery of care outlined above, echo in the training of vascular surgeons. Vascular surgery programs in LMICs are often limited, in part, due to a lack of funding for training programs.[5,58] In countries with these limitations, there are only a handful of available positions, certainly not enough to meet the current demand for vascular surgeons. Those fortunate enough to secure a position often have a salary below the living wage or go unpaid.[58]

Access to the proper equipment to train rising vascular surgeons is another important consideration in LMICs. The inadequate infrastructure and supplies found in many LMICs hinder the quality and scope of training provided.[58] Increasing funding, capacity, and infrastructure for the education of vascular surgeons will allow for increased access to surgical services and a higher quality of care.

Ideas put forth to achieve these goals include international collaboration through partnered training programs, increased recognition of vascular surgery as a distinct specialty, increasing awareness of vascular surgery as a specialty among the public as well as medical students and early trainees, and increasing funding of training

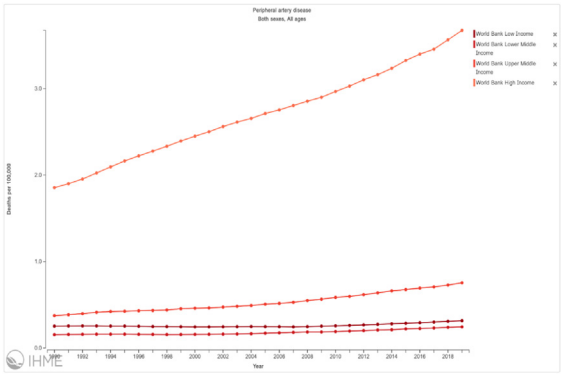

Fig. 7. Deaths per 100,000 people due to aortic aneurysm between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

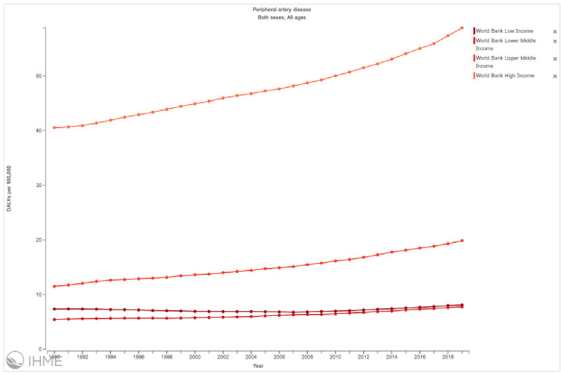

Fig. 8. DALY per 100,000 people due to aortic aneurysm between 1990 and 2019. Figure from Institute of Health Metrics and Evaluation. Available at: https://www.healthdata.org/.

programs to increase capacity and quality.[5,6,55,58] Though these ideas may be more easily implemented in wealthier nations, it is important to direct efforts and collaboration toward LMICs to promote a global increase in vascular surgeon accessibility. A successful example of international collaboration is the vascular surgeon exchange program between Linköping University Hospital in Sweden and Tikur Anbessa Specialized Hospital (TASH) in Ethiopia. This exchange program allowed for mutual benefit: 1 Ethiopian vascular surgeon and 4 fellows and residents were trained in techniques such as below-knee anastomoses and vascular access techniques while 5 vascular surgeons from Sweden gained experience in open access vascular surgeries.[27] Besides the immediate benefit of improved surgical technique, this program also served to increase capacity for vascular surgical services in Ethiopia as it fostered the development of a formal training curriculum through which subsequent surgeons may be trained.[27] The implementation of programs such as this one may result in global increased capacity of and access to vascular surgery, thereby increasing supply as demand continues to rise.

Limitations

While shedding light on important aspects of global vascular surgery, this paper does have some limitations. Primary among them is the fact that AA, PAD, and IS do not encompass all cardiovascular disease. In reality, cardiovascular disease poses a much greater burden of disease than that estimated in this study. Therefore, the need for vascular surgeons is, in fact, understated in these findings.

Further limitations pertain to the data utilized in this study. The first of these is the inability to ascertain whether the increasing burden of disease is solely due to a true increase in disease incidence or prevalence. It is plausible that this increase can be attributed to improved data collection in some regions. Moreover, autopsies are not routinely performed to confirm the cause of death in the data provided by the IHME Global Burden of Disease Results Tool. As such, the possibility that a death may be attributed to an incorrect cause remains.

Another limitation is the limited scope of data collection and research focused on global vascular surgery. The results of the literature review yielded a limited number of studies and research efforts focused on global vascular surgery. This is in part due to a lack of inclusion of the global south in vascular data registries. The registries currently in existence consist mainly of countries in the global north, severely limiting the amount of data collected regarding vascular surgery in low and middle income countries. Increasing the scope of vascular surgery data collection efforts in LMICs may facilitate better quantification of quality and access in these countries.

CONCLUSION

The global south, consisting predominantly of LMICs, continues to face a disproportionate prevalence and incidence of CVD, while not benefitting from the same technological advances and increased surgical capacity enjoyed in the global north. LMICs shoulder a greater burden of disease in terms of deaths and DALYs due to AA, PAD, and IS. Moreover, LMICs have seen a steeper upward trend in

the rate of death and DALYs due to these 3 diseases between 1990 and 2019. These regional disparities have persisted over time, necessitating a concerted approach to increasing vascular surgery access and capacity.

Increased access to vascular surgery services may be achieved through interventions targeting financing and infrastructure, patient knowledge and beliefs, workforce development, and data collection and dissemination. Improved access to vascular surgeons is a goal within reach. It requires, however, global collaboration and the development of intentional, sustainable interventions, and processes.

REFERENCES

1. Belkin M. The training of firemen. J Vasc Surg 2014;59:1144–51.
2. Veith FJ. A look at the future of vascular surgery. J Vasc Surg 2016;64:885–90.
3. Štádler P, Dorosh J, Dvořáček L, et al. Review and current update of robotic-assisted laparoscopic vascular surgery. Semin Vasc Surg 2021;34:225–32.
4. Cooper MA. Technological innovations in vascular surgery: current applications and future directions. Semin Vasc Surg 2021;34:161–2.
5. Education in vascular surgery—critical issues: a Southern African perspective - Journal of vascular surgery, https://www.jvascsurg.org/article/S0741-5214(08)01501-2/fulltext. Accessed March 24, 2023.
6. Sekar N. Education in vascular surgery: critical issues in India. J Vasc Surg 2008;48:76S–80S.
7. Quantifying international access to cardiac, thoracic & vascular. AATS, https://www.aats.org/resources/quantifying-international-access-to-cardiac-thoracic-vascular-surgery. Accessed November 18, 2022.
8. Fowkes FGR, Aboyans V, Fowkes FJI, et al. Peripheral artery disease: epidemiology and global perspectives. Nat Rev Cardiol 2017;14:156–70.
9. GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021;20:795–820.
10. Wei L, Bu X, Wang X, et al. Global burden of aortic aneurysm and attributable risk factors from 1990 to 2017. Glob Heart 2021;16:35.
11. Moran AE, Narula J. Secondary prevention of CVD in LMIC: care for the growing affected population. Glob Heart 2017;12:271–2.
12. Roth GA, Johnson C, Abajobir A, et al. Global, regional, and national burden of cardiovascular diseases for 10 causes, 1990 to 2015. J Am Coll Cardiol 2017;70:1–25.
13. World Health Assembly Resolution WHA68.15: ''Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage''—addressing the public health gaps arising from lack of safe, affordable and accessible surgical and anesthetic services | SpringerLink, https://link.springer.com/article/10.1007/s00268-015-3153-y. Accessed December 28, 2022.
14. GBD Results. Institute for Health Metrics and Evaluation, https://vizhub.healthdata.org/gbd-results. Accessed December 28, 2022.
15. How we collect data. Institute for Health Metrics and Evaluation, https://www.healthdata.org/data-tools-practices/data-collection; 2016. Accessed May 8, 2023.
16. GBD Publications. Institute for Health Metrics and Evaluation, https://www.healthdata.org/gbd/publications; 2014. Accessed May 8, 2023.
17. World Bank Open Data | Data, https://data.worldbank.org/?most_recent_year_desc=false. Accessed March 24, 2023.
18. Vascular Specialists | Society for Vascular Surgery, https://vascular.org/. Accessed March 24, 2023.
19. CTSNet | the Cardiothoracic Surgery Network, https://www.ctsnet.org/. Accessed March 24, 2023.
20. Noncommunicable diseases, https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases. Accessed March 24, 2023.
21. Results report 2022 - the global Fund to Fight AIDS, tuberculosis and malaria, https://www.theglobalfund.org/en/results/#hiv. Accessed March 24, 2023.
22. Eid MA, Mehta K, Barnes JA, et al. The global burden of peripheral artery disease. J Vasc Surg 2023;77:1119–1126.e1.
23. Liu W, Yang C, Chen Z, et al. Global death burden and attributable risk factors of peripheral artery disease by age, sex, SDI regions, and countries from 1990 to 2030: results from the Global Burden of Disease study 2019. Atherosclerosis 2022;347:17–27.
24. Mouyarden O, Bakkali T, Azghari A. Vascular surgery in Morocco: challenges and perspectives. Eur J Vasc Endovasc Surg 2022;64:1–3.
25. Cassimjee I, Roux D le, Pillai J, et al. Vascular surgery in South Africa in 2021. Eur J Vasc Endovasc Surg 2021;61:719–20.
26. Hassani M, Nozarinia M, Marashi SA. COVID-19 disease, its challenge for Iranian vascular surgeons and our works. Iran J Vasc Surg Endovasc Ther 2021;1:14–8.
27. Lundgren F, Hodza-Beganovic R, Johansson M, Seyoum N, Tadesse M, Andersson P. A vascular surgery exchange program between Ethiopia and Sweden: a plus for both. IJS Global Health 2020;3:e43.
28. Wilkinson E, Aruparayil N, Gnanaraj J, et al. Barriers to training in laparoscopic surgery in low- and middle-income countries: a systematic review. Trop Doct 2021;51:408–14.
29. Bedwell GJ, Dias P, Hahnle L, et al. Barriers to quality perioperative care delivery in low- and middle-income countries: a qualitative rapid appraisal study. Anesth Analg 2022;135:1217.
30. Edaigbini SA, Delia IZ, Aminu MB, Bosan IB, Ibrahim A, Anumenechi N. Vascular surgeries in West Africa: challenges and prospects. Asian Cardiovasc Thorac Ann 2015;23:552–7.
31. Gyedu A, Stewart BT, Nakua E, et al. Assessment of risk of peripheral vascular disease and vascular care capacity in Ghana. Br J Surg 2016;103:51–9.
32. Stewart BT, Gyedu A, Giannou C, et al. Consensus recommendations for essential vascular care in low- and middle-income countries. J Vasc Surg 2016;64:1770–1779.e1.
33. Understanding surgical care delivery in Sub-Saharan Africa: a cross-sectional analysis of surgical volume, operations, and financing at a tertiary referral hospital in rural Tanzania - PMC, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6816166/. Accessed March 24, 2023.
34. Okoroh JS, Chia V, Oliver EA, et al. Strengthening health systems of developing countries: inclusion of surgery in universal health coverage. World J Surg 2015;39:1867–74.
35. Baatiema L, Otim M, Mnatzaganian G, et al. Towards best practice in acute stroke care in Ghana: a survey of hospital services. BMC Health Serv Res 2017;17:108.

36. Chawla S, Kurani S, Wren SM, et al. Electricity and generator availability in LMIC hospitals: improving access to safe surgery. J Surg Res 2018;223:136–41.
37. Athanasiov PA, Casson RJ, Newland HS, et al. Cataract surgical coverage and self-reported barriers to cataract surgery in a rural Myanmar population. Clin Experiment Ophthalmol 2008;36:521–5.
38. Oliva MS, Munoz B, Lynch M, et al. Evaluation of barriers to surgical compliance in the treatment of trichiasis. Int Ophthalmol 1997;21:235–41.
39. Gage AJ. Barriers to the utilization of maternal health care in rural Mali. Soc Sci Med 2007;65:1666–82.
40. Parkhurst JO, Rahman SA, Ssengooba F. Overcoming access barriers for facility-based delivery in low-income settings: insights from Bangladesh and Uganda. J Health Popul Nutr 2006;24:438–45.
41. Chandrashekhar TS, Bhat HV, Pai RP, et al. Coverage, utilization and barriers to cataract surgical services in rural South India: results from a population-based study. Public Health 2007;121:130–6.
42. Predictors of and barriers associated with poor follow-up in patients with Glaucoma in south India | Glaucoma | JAMA Ophthalmology | JAMA Network, https://jamanetwork.com/journals/jamaophthalmology/fullarticle/420863. Accessed March 24, 2023.
43. Seljeskog L. Factors Influencing Women's Choice of Place of delivery in rural Malawi: - an Explorative study. Master Thesis, https://www.duo.uio.no/handle/10852/29793; 2007. Accessed March 24, 2023.
44. Touray S, Sanyang B, Zandrow G, et al. Incidence and outcomes after out-of-hospital medical emergencies in Gambia: a case for the integration of prehospital care and emergency medical services in primary health care. Prehospital Disaster Med 2018;33:650–7.
45. Chu K, Maine R, Duvenage R. We asked the experts: the role of rural hospitals in achieving equitable surgical access in low-resourced settings. World J Surg 2021;45:3016–8.
46. Gloviczki P. The science and art of vascular surgery has no country. J Vasc Surg 2008;48:1S–10S.
47. Sutzko DC, Mani K, Behrendt CA, et al. Big data in vascular surgery: registries, international collaboration and future directions. J Intern Med 2020;288:51–61.
48. White JV, Conte M, Bradbury A, et al. Building a global alliance in vascular surgery. J Vasc Surg 2019;70:663–4.
49. ICVR. MDEpiNet Site, https://www.mdepinet.net/icvr. Accessed March 24, 2023.
50. Surgical need in an ageing population: a cluster-based household survey in Nepal - the Lancet, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60800-5/fulltext. Accessed March 24, 2023.
51. Stewart BT, Gyedu A, Abantanga F, et al. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. World J Surg 2015;39:2613–21.
52. Bowman RJC, Faal H, Jatta B, et al. Longitudinal study of trachomatous trichiasis in the Gambia: barriers to acceptance of surgery. Invest Ophthalmol Vis Sci 2002;43:936–40.
53. Abaraogu UO, Dall PM, Seenan CA. The effect of structured patient education on physical activity in patients with peripheral arterial disease and intermittent claudication: a systematic review. Eur J Vasc Endovasc Surg 2017;54:58–68.
54. Eastridge DK. An integrative review of interventions to reduce peripheral arterial disease risk factors in African Americans. J Vasc Nurs 2009;27:31–45.
55. Vascular surgery training and certification: an international perspective - Journal of Vascular Surgery, https://www.jvascsurg.org/article/S0741-5214(07)01069-5/fulltext. Accessed March 24, 2023.
56. Avgerinos ED, Aksoy M, Bisdas T, et al. Vascular training profiles across Europe. Eur J Vasc Endovasc Surg 2013;46:719–25.
57. Arous EJ, Judelson DR, Simons JP, et al. Increasing the number of integrated vascular surgery residency positions is important to address the impending shortage of vascular surgeons in the United States. J Vasc Surg 2018;67:1618–25.
58. Moreira RCR. Critical issues in vascular surgery: education in Brazil. J Vasc Surg 2008;48(6 Supplement):87S–9S.