Mobile ultrasound vascular assessment (MUVA) for remote and conflict areas

Oscar Y. Moreno Rocha
Medical School, Universidad de los Andes, Bogota, Colombia; Division of Vascular and Endovascular Surgery, Fundación Santa Fe de Bogota University Hospital, Bogota, Colombia and Department of Vascular Surgery, University of Michigan, Ann Arbor, Michigan, USA

Paula Pinto
Medical School, Universidad de los Andes, Bogota, Colombia and Division of Vascular and Endovascular Surgery, Fundación Santa Fe de Bogota University Hospital, Bogota, Colombia

Maria C. Consuegra
Medical School, Universidad del Norte, Barranquilla, Colombia, and

Sebastian Cifuentes and Jorge H. Ulloa
Medical School, Universidad de los Andes, Bogota, Colombia and Division of Vascular and Endovascular Surgery, Fundación Santa Fe de Bogota University Hospital, Bogota, Colombia

Abstract

Purpose – This study aims to facilitate access to vascular disease screening for low-income individuals living in remote and conflict areas based on the results of a pilot trial in Colombia. Also, to increase the amount of diagnosis training of vascular surgery (VS) in civilians.

Design/methodology/approach – The operation method includes five stages: strategy development and adjustment; translation of the strategy into a real-world setting; operation logistics planning; strategy analysis and adoption. The operation plan worked efficiently in this study's sample. It demonstrated high sensibility, efficiency and safety in a real-world setting.

Findings – The authors developed and implemented a flow model operating plan for screening vascular pathologies in low-income patients pro bono without proper access to vascular health care. A total of 140 patients from rural areas in Colombia were recruited to a controlled screening session where they underwent serial noninvasive ultrasound assessments conducted by health professionals of different training stages in VS.

Research limitations/implications – The plan was designed to be implemented in remote, conflict areas with limited access to VS care. Vascular injuries are critically important and common among civilians and military forces in regions with active armed conflicts. As this strategy can be modified and adapted to different medical specialties and geographic areas, the authors recommend checking the related legislation and legal aspects of the intended areas where we will implement this tool.

Practical implications – Different sub-specialties can implement the described method to be translated into significant areas of medicine, as the authors can adjust the deployment and execution for the assessment in peripheral areas, conflict zones and other public health crises that require a faster response. This is necessary, as the amount of training to which VS trainees are exposed is low. A simulated exercise offers a novel opportunity to enhance their current diagnostic skills using ultrasound in a controlled environment.

Social implications – Evaluating and assessing patients with limited access to vascular medicine and other specialties can decrease the burden of vascular disease and related complications and increase the number of treatments available for remote communities.

Originality/value – It is essential to assess the most significant number of patients and treat them according to their triage designation. This management is similar to assessment in remote areas without access to a proper VS consult. The authors were able to determine, classify and redirect to therapeutic interventions the patients with positive findings in remote areas with a fast deployment methodology in VS.

Plain language summary – Access to health care is limited due to multiple barriers and the assessment and response, especially in peripheral areas that require a highly skilled team of medical professionals and related equipment. The authors tested a novel mobile assessment tool for remote and conflict areas in a rural zone of Colombia.

Keywords Flow assessment, Assembly line, Aortic aneurysm, Chronic venous disease, Ultrasound, Combat casualty care

Paper type Research paper

The authors sincerely thank the National Colombian Vascular Surgery Association – Asovascular, who helped coordinate this event's execution and planning and their collaborators.

Received 20 April 2022
Revised 11 September 2022
4 February 2023
Accepted 9 June 2023

The current issue and full text archive of this journal is available on Emerald Insight at: **https://www.emerald.com/insight/2042-6747.htm**

Journal of Humanitarian Logistics and Supply Chain Management
14/2 (2024) 171–180
Emerald Publishing Limited [ISSN 2042-6747]
[DOI 10.1108/JHLSCM-04-2022-0047]

An executive summary for managers and executive readers can be found at the end of this article.

Introduction

In 1979, the *product-process matrix* business theory described that for a company to be successful, it requires a similar stage between product manufacturing and personalization (Hayes and Wheelwright, 2021). A principle that is highly applied to surgery. Nevertheless, surgery can be understood as a process, a service or a product (Swink *et al.*, 2020). Specifically, in vascular surgery (VS), treating patients is a service aiming for better health outcomes. VS is highly personalized regarding the assessment, management and follow-up of several diseases. Therefore, it can be compared to the *Job shop* type of production system, given that highly personalized surgeries are performed in an intermediate production volume and are often related to a high cost. The modern practice of VS can be referred to as a tailor-made process (aortic aneurysm open planning and repair: venous endovascular interventions: amputations) (Dolan, 2020; Isacson, 2023; Ríos, 2018; The Economist, 2015).

The challenge of deploying and managing injured civilians has caused much interest in developing more efficient and safe diagnostic and therapeutic interventions. Portable ultrasound assessment in VS civilian institutions enhanced the knowledge, skills and abilities (KSAs) in VS care (Holt *et al.*, 2021). This is critically important in regions such as Colombia and Afghanistan, where combat casualties and mass injuries from improvised explosive devices are seen. Recently massive trauma victims from public shootings and other mass casualties also persist (Hall *et al.*, 2021; Porta *et al.*, 2014; Turner *et al.*, 2016; Elster *et al.*, 2013). According to the 2021 published data of the US Association of Military Surgeons, most medical treatment facilities in the USA do not provide enough clinical exposure for general surgeons to achieve the readiness for developing the required KSAs needed for combat casualty care (Dalton *et al.*, 2022).

Besides implementing *Clinical Readiness Programs* in Health Systems, local health services should be trained in simulated scenarios with variable levels of deployment preparedness in risk and remote areas to improve readiness and health-care access. This strategy aims to enhance the KSA's faculties and readiness required for pathological vascular diagnosis using mobile ultrasound vascular assessment (MUVA) and impacts three main areas: public health, social justice and medical education. Massive screening for vascular diseases allows early identification of pathologies and reduces the health system's burden related to severe complications. Abdominal aortic aneurysms (AAA) are life-threatening conditions in which an intimal degeneration produces enlargement and weakening of the aortic wall, predisposing it to rupture. AAA prevalence in the Americas is estimated at 2.2% in the general population (Li *et al.*, 2013). However, epidemiological data on this disease in Colombia is limited. One report estimated AAA prevalence as low as 1% (García *et al.*, 2008). Nonetheless, the sample size was too small. Given the uncertainty of the epidemiological distribution of AAA in Colombia and the high mortality rates of up to 58% (Karthikesalingam *et al.*, 2014) after aneurysmal rupture, early identification prevents devastating consequences for patients and complex care plan expenses for health systems.

In addition to AAA, our strategy focused on screening for superficial venous insufficiency (SVI), a disease with a high impact on patient's health and quality of life. SVI prevalence in the general population has been reported as 21% (Tsukanov and Tsukanov, 2017), and complications can range from severe lower limb pain, varicosities and edema to deep vein thrombosis, pulmonary embolism and venous leg ulcerations. This disease can severely affect patients' quality of life if left untreated. Therefore, a prompt diagnosis can help to provide early treatment, which can vary from simple leg elevation at the end of the day to highly effective minimally invasive ablation of the incompetent veins (Ulloa *et al.*, 2021). In this protocol, patients were screened for both AAA and SVI, and those with a significant disease warranting treatment were referred to specialized centers to receive appropriate care.

Literature review

Colombia has been involved since the 1960s in an internal conflict around cocaine and drug production, mainly executed by illegal guerilla groups (Offstein and Aristizábal, 2003; Camargo *et al.*, 2014). The internal war has affected a large volume of the Colombian population, which is over 20% rural and lives under minimum wage (García *et al.*, 2022). Interestingly, the most common injury mechanism in the Colombian conflict is gunshot wounds rather than blast injuries, which was the most prevalent in Iraq and Afghanistan (Ministerio de Agricultura y Desarrollo Rural, 2021). The extensive Colombian conflict and the war in different countries have contributed to the advancements in managing vascular trauma (Asensio *et al.*, 2015; Rasmussen *et al.*, 2008; Daniels, 2016; Caicedo *et al.*, 2022).

The Colombian health-care system has become prolific in handling trauma settings. However, the vulnerable population still has limited access to specialized medical care, such as VS. A recent report by Correa *et al.* describes the characteristics of a large sample of patients seen at a private, outpatient specialized clinic to manage chronic venous disease in Colombia (Correa Posada *et al.*, 2022). This study concludes that over 78% of patients are women, and up to 10% can suffer from severe manifestations of venous disease such as ulceration and varicorrhage. In addition, a study conducted by Ulloa Dominguez *et al.* (2018) found that 17% of patients with chronic venous disease suffer from concomitant hypothyroidism, which, if untreated, can significantly affect their quality of life.

In summary, our proposed MUVA strategy tackles a lack of access to VS for vulnerable people in Colombia. A complete description of logistics and staff requirements makes our work replicable and suitable for expansion to other areas and diseases. To our knowledge, no reports are available about how to conduct a strategy for providing specialized medical screening to a large group of patients in a time- and cost-effective manner. The MUVA strategy focuses on two vascular diseases, chronic venous disease (CVD) and abdominal aortic aneurysm. CVD is a highly prevalent and morbid disease that can significantly affect the quality of life and be associated with concomitant comorbidities. AAA is not highly prevalent in

Colombia or perhaps is under-reported; however, screening for this condition is justified based on the outrageously high mortality rates (up to 80%) that an undetected aneurysm has if ruptured (Kühnl *et al.*, 2017).

Our strategy represents a pioneering plan in Colombia to contribute to social justice and access to health care for those in need. Colombia's social and economic landscape is characterized by significant inequity in resource distribution, with more than 50% of the country's income being held by the wealthiest 20% of the population (Romero, 2022). This tendency continues in health-care access. Being incredibly challenging for the rural population to receive specialized care in areas such as VS. Accordingly, our strategy allowed several individuals who had never been assessed for vascular diseases to receive an integral examination by certified personnel identifying diseases and receiving a treatment plan at no expenses for the patient.

The third field that our study impacts significantly is medical education. Our staff included medical practitioners in several stages of training, from medical students to vascular surgeons, nurses and supporting staff. Our strategy allowed patients to receive care at different levels of care and personnel in training to have hands-on experience with many patients. All the interventions and patient contact were supervised by vascular surgeons, ensuring safety and proper performance. Evidence has demonstrated that experimental learning is the most effective way to integrate medical theory into practice (Yardley *et al.*, 2012). However, access to personnel in training to direct hands-on experience might be limited in a hospital setting due to limited time, high availability of medical staff and regulatory policies. Thus, our strategy model represents an excellent opportunity for personnel in training to increase expertise and self-confidence in VS competencies and patient-doctor interaction skills.

Additional ultrasound uses in remote areas

In remote and conflict areas, portable ultrasound has the potential to play a significant role in providing medical care and support. Portable ultrasound has potential applications in triage and emergency medical response, assessment of war-related injuries, improved maternal and fetal health monitoring and diagnosis and monitoring of infectious diseases (elephantiasis, filariasis and onchocerciasis) (Becker *et al.*, 2016; Harris and Marks, 2009; Stewart *et al.*, 2020; Toscano *et al.*, 2021; Marriott *et al.*, 2018). The use of portable ultrasound can help to address the lack of access to medical facilities in these areas, providing quick and reliable diagnoses and treatments. Further research and development are needed to fully realize the potential of portable ultrasound in remote and conflict zones. Non-medical applications include veterinary care in rural areas (pregnancy diagnosis, fetal health assessment and evaluation of reproductive organs in livestock). These applications demonstrate the versatility and usefulness of portable ultrasound in improving health outcomes in rural areas with limited access to health care.

Methodology

In the first stage, the National Colombian Vascular Surgery Association started developing a strategy to provide an algorithm capable of reaching vulnerable populations consistently. We contacted several organizations to guarantee standardized, high-quality attention. Afterward, we assessed the characteristics of the targeted population, coordinated the visit and elaborated a field report. The protocol was designed to execute in 12 hours. We distributed the 20 volunteers into six roles, each responsible for specific data recollection. After the screening and triaging of patients, vascular surgeons proceeded to provide therapeutic interventions if needed. Our strategy represents a pioneering plan in Colombia to contribute to social justice and access to health care for those in need. Colombia's social and economic landscape is characterized by significant inequity in resource distribution. More than 50% of the country's income is held by the wealthiest 20% of the population, even with national monetary poverty of 39.3% and extreme monetary poverty of 12.2% (DANE, 2022).

This tendency continues in health-care access. Health care in Colombia is fragmented, providing care according to employment status and income. Financial limitations translate into infrastructure, personnel and medication deficiencies that, combined with fragmentation, result in disparities in access and ineffective health coverage (Báscolo *et al.*, 2018). Although insurance covered almost 91% of the population in 2012, the country still needs to improve adequate access and health-care quality to the same extent (Londoño and Molano, 2015). Therefore, marginalized people become even more vulnerable to health complications due to their lack of access to effective surveillance and primary preventative strategies. The latter becomes vital because of the armed conflict in this territory and because Colombia is the largest recipient of Venezuelan immigrants totaling more than 2.2 million in 2022 (La República, 2022). Accordingly, our strategy allowed several individuals who had never been assessed for vascular diseases to receive an integral examination by certified personnel to identify pathologies and receive a treatment plan at no expense to the patient.

Facility location models in humanitarian operations

Similar approaches have been previously implemented in other areas of medicine, including surgery departments, accident settings and emergency departments (La República, 2022; Antonelli and Taurino, 2010). Despite public health efforts toward finding an efficient method for specialized medicine access for remote areas, there has yet to be successful coverage in rural areas for sub-developed countries and other remote locations with difficult topographical access (Walley, 2003; Calderón *et al.*, 2011; Cardona *et al.*, 2021; Escobar *et al.*, 2021). Although several strategies such as telehealth and 5G methodologies have been implemented to fulfill this necessity, the infrastructure costs and execution limit this approach (Mogollón-Pérez and Vázquez, 2008; Paudel and Bhattarai, 2023; Memos *et al.*, 2023). Particularly, in Colombia, the burden of silent vascular diseases has yet to be quantified, and few national health policies address these diseases (Paudel and Bhattarai, 2023; Memos *et al.*, 2023; Lacy *et al.*, 2019; Cataño Bedoya *et al.*, 2015; Botero and Jaramillo, 2023; Ramirez and Norman, 2009). We developed and executed a controlled civilian MUVA as an efficient, scalable and generic assembly line to screen aortic aneurysms, chronic venous disease and carotid stenosis diseases. This tool is helpful in Colombia because multiple remote areas need proper access to hospital infrastructure, vascular surgeons and diagnostic equipment (such as portable ultrasound systems). We tested the mentioned strategic plan on 140 patients in a single-day event measuring different performance metrics. The checklist requirements for this deployment are explained in Table 1. with a suggested number of items based on the volume of patients intended to assess.

Vascular assessment optimization strategy

The optimization strategy for the combined *job shop* to the *batch production* model that VS uses to assess the more significant number of patients without access to a proper VS consult is based on the strategic and operating plan developed in Figure 1. We designed this methodology prototype by applying a business state-of-the-art *Closed-Loop Management System* design for Strategy and Operations (Buitrago *et al.*, 2011). It consists of five stages:

1 strategy development and adjustment;
2 translation of the strategy into a real-world setting;
3 operation logistical planning;
4 operation conduction and monitoring; and
5 strategy analysis and adoption.

We selected this methodology due to its capability to be improved during its execution. Steps 1–3 were improved using the FMEA tool by classifying possible failure models by risk factors of occurrence (O), severity (S) and detection (D) (Kaplan and Norton, 2008). Steps 4–5 were improved using the RCA tool by identifying the new problem, measuring the impact on time, identifying the causal factors, implementing corrective actions and measuring the new outcomes (Liu *et al.*, 2020).

Stage 1: strategy development and adjustment

We aimed to fulfill the purpose of offering a specialized and standardized evaluation for populations with difficult access to VS consult, focusing on diagnosing AAA, SVI and carotid stenosis, which often leads to increased morbidity and mortality. With this tool, we aimed to offer vascular health-care access to patients in disadvantaged populations following the ethical values of justice and beneficence and, in the process, train the future health-care personnel required to fulfill this purpose. We contacted human resources, governmental and health-care organizations necessary to guarantee the deployment. Portable ultrasound was the central enabling technology; we previously identified the execution of this tool to ensure continuous assessment. Moreover, the efficiency of assessments was the critical performance metric, as the only available vascular access to these populations depends on the working staff's designated time, safety conditions and the available waiting period of the patients. Nevertheless, guaranteeing standardized and high-quality attention is another pillar of the described attention model.

Stage 2: translation of the strategy into a real-world setting

Developing a strategy focused on efficiency and high-quality assessment in VS can only be done by planning, practicing the execution of the process and working with a multidisciplinary team with straightforward pre-established tasks (Swink *et al.*, 2020). The main pre-selected areas for developing this strategy are described below:

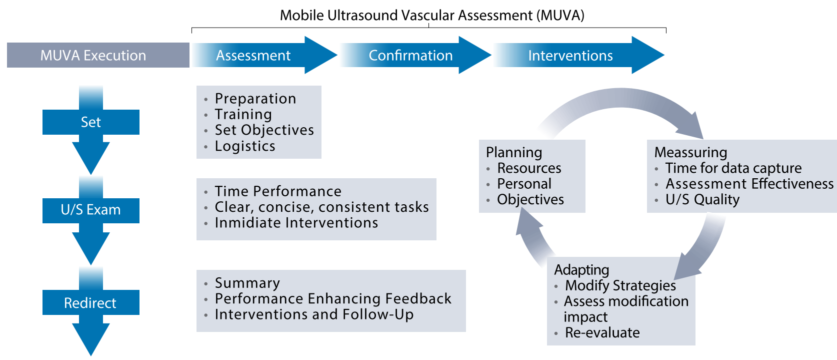
- *High-risk populations*: To significantly impact the community, we searched for populations with limited access to a VS consult. We did this search within a 50-km radius of the capital city of Colombia. We agreed to develop this strategy in a closed area, as this was the first time we executed this type of deployment in a complex rural territory without any external ground or aerial support.
- *Field analysis*: Once we established the selected high-risk population, we coordinated the first official invitation to

Table 1 Checklist for mobile ultrasound vascular assessment (MUVA) implementation

Target population	***Approximate number of intended patients to be assessed (ANIPA)***		
Resources	**ANIPA# 100–300**	**ANIPA# 500–800**	**ANIPA# >1000**
Vascular personal	20–25	30–50	50–80
Coordination personal	5–10	10–25	25–40
Portable ultrasound equipment	3–5	5–10	10–15
Blood pressure equipment for Brachial Ankle index	2–3	3–5	5–10
Weight machine and retractable medical Body tape measure	1–2	2–5	5
Data caption system	1 main online platform and a backup plan option (like written records, other online tools)		
Food and water for staff	1–2 light meals, 1 complete meal and 2–3 bottles of water per volunteer for a duration of <8 hours		
	2–3 light meals, 2 complete meals and 3–4 bottles of water per volunteer for a duration of >8 hours		
Educational information for patients	1 member of staff	3 members of staff	10 members of staff
Identifications	1 for every member of staff		
Raincoats	1 for every member of staff		
Sunscreen lotion	1 bottle per every 10 staff members		
Exam Rooms	4–6	8–10	10–15
Portable examining tables	Same as exam rooms		
Portable changing rooms	2–3	3–5	5–7

Source: Table created by author

Figure 1 Mobile ultrasound vascular assessment (MUVA) strategic and operating plan for mass vascular assessment

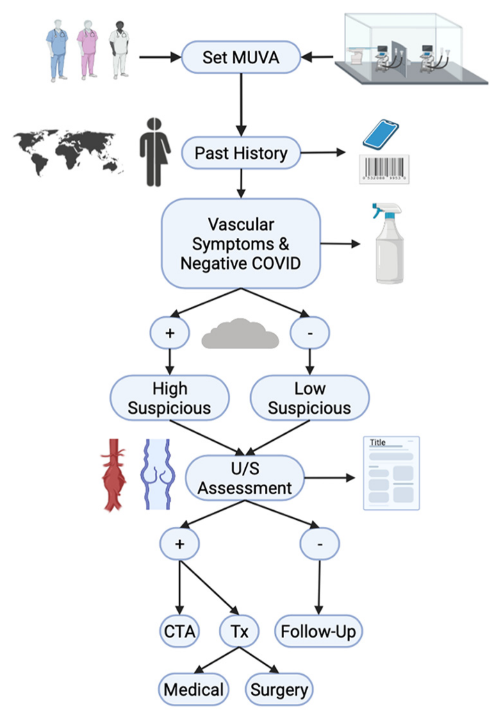


Source: Figure created by authors

the delegates. After mutual agreement on appropriate dates, we included personal and necessary workspaces. Finally, we elaborated a field report including access routes, travel time, weather conditions, safety conditions and available installations for patient attention.

- *Specialized personnel selection*: We could not directly hire qualified personnel for the ultrasound evaluation due to limited funds. We decided to coordinate a *Non-Governmental Organization* approach by contacting different vascular surgeons across the country to execute and deploy this strategy. The principal method was to get the *National Colombian Vascular Surgery Association* (Asovascular) vascular surgeons database and coordinate the invitations of surgeons and other required staff volunteers through their human resources staff.
- *Patients invitation*: Once we established the required resources for our strategy, we made projections of the necessary time for the entire execution of the assessment tool for a one-day event. We selected the number of patients to be included based on the average assessment time to complete the process. Subsequently, we contacted the patients by phone and confirmed their participation in this event. We subdivided them into four groups since the workflow of the chosen local business was limited. We planned three screening stations for chronic venous disease, AAA and carotid artery disease, designed in a continuous production work line fashion. The flow assessment methodology can be seen in Figure 2.

Figure 2 MUVA flow assessment methodology



Source: Figure created by authors

Stage 3: operation logistical planning

On September 8, 2021, we executed our deployment in the field. Methodology modifications and adaptability of our staff were required to improve patient assessment. Additional volunteers were needed to fulfill roles for operations that were not contemplated in the initial strategy by the preemptive FMEA methodology. Some of the techniques that required improvement during the event execution are mentioned in the following sections:

- *Volunteer redistribution*: Initially, there were approximately 20 volunteers to assess 140 patients. We assigned two volunteers at the entrance to organize all the patients in a line and provide them with their unique national identification (ID) numbers to record their information efficiently in the cloud. Four additional volunteers recollected sociodemographic data, and one guided the patients to the screening module. Three volunteers (one per cubicle) were in charge of recollecting the data provided by the three vascular surgeons in charge of the screening for vascular diseases (AP aortic diameter, ankle-brachial index [ABI] and saphenous competency). Two other volunteers performed the measure of the ABI index. The other two volunteers were in charge of patient education, and the last supervised the operation. To enhance learning opportunities for medical students, we organized the functions in groups that rotated and changed their roles with every subgroup of patients.
- *Data collection*: Originally, data recollection was intended to be done on a single Google Form available to every staff member through their phones. Nevertheless, we realized

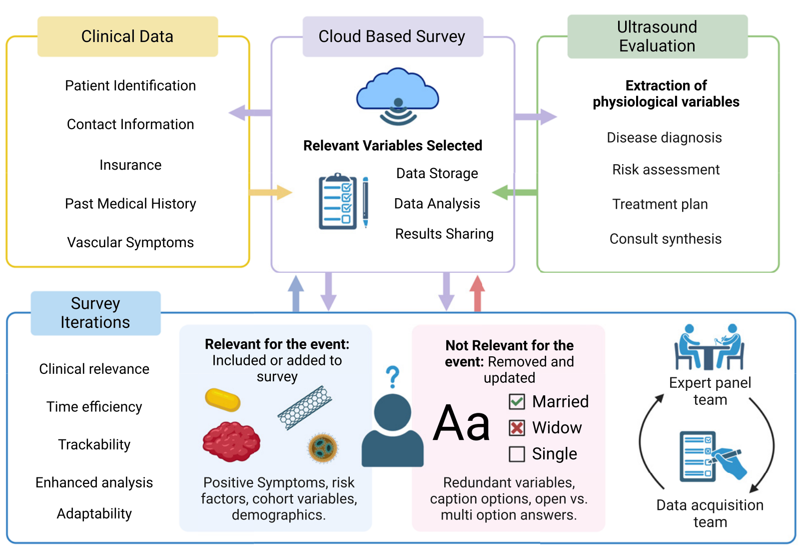
that a subdivision approach was more efficient with the first subgroup of patients due to extensive demographic and past medical history information. We used their ID number to record and unify the data into a single database during the event. We developed three different versions of data caption until we achieved the most efficient and appropriate design mentioned in Figure 3. The vascular surgeons made these recommendations to record the most valuable information based on their experience.

- *Screening application*: The initial patients were introduced into the screening module on a single fashion line, but the increased assessment time led us to a more flexible approach, where more than one module was used simultaneously in an inter-changed approach. For example, once the patients finished the screening for an aortic aneurysm (because it was available), they could continue with the ABI measure until they completed the three-step screening assessment. For assessing the mentioned vascular conditions, we required an enclosed space due to the limitations of ultrasound interpretation under sunny conditions limiting the available areas for vascular evaluation. The 5 MHz transducer was used for aortic diameter measurement, and an aortic diameter that exceeded 3 cm was referred for follow-up. The protocol used for SVI screening consisted of a reflux study with ultrasound on the great saphenous and small saphenous veins. Both vein size and the presence of reflux were evaluated. Finally, peripheral arterial disease was screened using ABI, and a ratio of less than 0.9 was considered diagnostic, requiring referral to a vascular specialist.
- *Limited resources*: Another improved aspect was the resource capacity plan adjustments. An unlimited flow of resources is impossible in remote access areas, and we had to adapt due to an increased number of patients not previously contemplated. First, we noticed that some portable ultrasound system batteries (POS) could not maintain continuous functioning. We surpassed this limitation by charging the POS during pauses between the different blocks of patients. Given the above, we suggest using portable equipment with the option to function plugged or rotate the devices being used to designate them to a charge period by increasing the number of available ultrasound devices. Also, by the end of the day, we ran out of gel for the ultrasound and disposable pants for the physical exam. Therefore, we propose calculating an approximate amount of limited resources needed for the intended number of patients to use but also include additional limited resources if possible.
- *Weather conditions*: Pre-contemplating the changeable conditions of the field is a critical factor for the attention of high-volume type deployments. All the staff members indicated the necessary precautions in case the conditions changed. Some of the considered measures were: umbrellas, sunscreen, buildings with external ceiling panels and floors with anti-slip coatings or tapes to guarantee a safe flow of the patients and staff even in rainy conditions. It is essential to ensure the secure deployment and packing methods for the ultrasound devices and other sensible materials required with waterproof cases.
- *Vascular interventions and follow-up*: Patients with a positive screening test for any of the three types of vascular diseases were scheduled for a follow-up appointment with a vascular surgeon. Surgical interventions, sclerotherapy or endovascular therapies were planned as needed.

Stage 4: operation conduction and monitoring

We executed different types of meetings for *Operational review*: to respond to short problems and promote continuous improvements; *Strategy review*: make fine adjustments to broader adaptations or implement a new strategy in the field; *Strategy testing and adapting*: to test and adapt the strategic changes based on the analytics to establish (if required) a new strategic plan. The primary coordinator and managers should

Figure 3 Data caption iterations methodology



Source: Figure created by authors

convene meetings to review departmental performance and resolve new problems. Developing performance indicators to identify barriers to the strategy execution is critically important:

- *Performance metrics*: The different modifications implemented were measured, reducing the operation time for a single patient assessed by more than one volunteer from 6’50” to 4’50”. The subdivided functions were also measured: Clinical records recollection from 3’40” to 60” (subdividing the data recollection). The physical exam, ultrasound, ABI index assessment and data recollection from 6’10” to 3’10” (adjusting the recollection form). The education for the patient was delivered from 60” to 50”.
- *Average time*: It took approximately 4–5 minutes per patient to complete each section. However, we required additional time for patients with high-risk factors for vascular disease or those with preexisting abnormalities that required further assessment.

Stage 5: strategy analysis and adoption

During the execution of this tool, we realized that some of the strategy’s assumptions needed to be revised. A final report was shared with all participants once the event was concluded. With the real-life execution of this operation, we could formulate approaches to expand the scope. The requirements checklist is listed in Table 1. with a suggested number of items based on the volume of patients intended to assess.

Statistical analysis

We analyzed the anonymized data in *SPSS Statistics 26.0*. We completed a descriptive study of the assessed variables, including risk factors for aortic aneurysms. A final report was constructed using *Document Studio from Digital Inspiration* from the *Google Workspace Market* and installed on *Sheets from Google Drive*. These reports were merged into customized documents and shared by email.

Results and discussion

We developed and executed a strategic plan to assess AAA, chronic venous disease and carotid stenosis with portable ultrasound systems for areas with limited access to VS. This assembly line-like design allowed us to help more patients than traditional models. In addition, the recollected data was used to describe the different risk factors and disease prevalence, updating the limited non-recent national data. The obtained results can serve as the first step to developing national, governmental and public health policies to address the burden of vascular diseases.

A total of 140 patients were enrolled in our pivot trial of MUVA. The protocol analyzed sociodemographic variables (age, gender, marital status, income, high weight, BMI), general risk factors for vascular diseases (smoking status, CVD familiar history, clinical signs of venous insufficiency such as edema, telangiectasias, pain) and clinical measures (anterior posterior (AP) aorta diameter, paucity of the internal carotid artery, presence of venous insufficiency of both great saphenous vein (GSV) and small saphenous vein (SSV) and the CEAP classification (Clinical-Etiological-Anatomical-Pathophysiological). Results are summarized in Table 2. We identified 30 patients registries with missing information (23.6%) when executing the data analysis in some of the variables. Patients without complete information were excluded from the final analysis. Our main finding was that 19 of 127 evaluated patients had chronic venous insufficiency in indication of surgical intervention and 1 patient had borderline measurement for abnormal aortic diameter. These patients were redirected with help of the national VS society to obtain further treatment.

Besides implementing this strategic plan in difficult access areas, we consider incorporating some of the main aspects of this tool and its developmental strategy in the in-hospital admission and treatment of patients with vascular pathologies. Implementing a focused, interdisciplinary, frontline and the provider-driven program has been proposed previously (Charles *et al.*, 2016). It has shown that we can feasibly incorporate it into an existing specialty surgical workflow.

Sharma *et al.* (2017) demonstrated that the incorporation of their program resulted in improved timeliness of discharge and

Table 2 Sociodemographic characteristics, comorbidities and VS pathologies

Total included patients	*n*: 125
Mean age	36.7 years (CI: 34.08, 38.45)
Average height	159.17 cm
Average weight	62.73 kg
Sex	Males 16.5%; Females 81.9%
Average BMI	24.4 kg/m^2
Marital status:	Single 38.6%
	Unmarried 41.7%
	Married 13.4%
	Divorced 5.5%
	Widowed 0.8%
Income	Low 89%
	Median 11%
Lives alone	Yes 10.2%
	No 89.8%
Active smoker	Yes → 21 (16.5%)
	No → 106 (83.5%)
History of venous insufficiency	Yes → 56 (55.9%)
	No → 71 (44.1%)
Edema of lower limbs	Yes → 19 (15%)
	No → 108 (85%)
Telangiectasias	Yes → 55 (43.3%)
	No → 72 (53.7%)
Pain	Yes → 46 (36.2%)
	No → 81 (63.8%)
AP aortic diameter (cm)	0.5–1.0 → 10 (11.3%)
	1.1–1.5 → 85 (96.05%)
	1.6–2.0 → 14 (15.8%)
	2.1–2.5 → 3 (3.39%)
	2.6–3.0 → 1 (1.13%)
CEAP classification	C0 → 53 (41.7%)
	C1 → 22 (17.3%)
	C2 → 17 (13.4%)
	C3 → 3 (2.4%)
	C4 → 2 (1.6%)
	C5 → 0
	C6 → 0
Chronic venous insufficiency	Right → 7 (5.5%)
	Left → 6 (4.7%)

Source: Table created by author

projected cost savings without increasing readmission rates. We obtained these results by implementing an enhanced communication program that recognizes the main factors associated with a delayed hospital discharge that translates into increased in-hospital mortality, decreased patient satisfaction and lost hospital revenue. Identifying and applying a new strategic plan through the recollected data of Sharma *et al.* (2017) exemplifies the role and advantages of changing from a robust model to a more flexible and adaptable organization. We believe that health care should focus more on identifying the barriers and bottlenecks that limit patients' access to enhanced vascular care.

Another essential aspect was the incorporation of interns, residents and vascular surgeons into the conditions of an emergency deployment. This activity can enhance the current KSAs required for a vascular ultrasound assessment. Incorporating telehealth consultation services can reduce the long waiting time for vascular appointments. Recently, there have been reports of seniors or even retired surgeons serving as consultants to procedures being done in remote parts of the earth without the academic formation of these experts for the execution of the required surgeries (Cofano *et al.*, 2021; van der Putten *et al.*, 2022).

The early identification of barriers to VS consult can be translated into model changes for the attention of vascular patients in the future. Extended access times for a specialized consult and access in remote areas are projected to increase based on the United Nations projections, given an increasingly aging population and associated vascular diseases. Therefore, it is critically important to evaluate and classify the patient, keep vigilance and develop better strategies for decreased average times to specialized medical attention. We can translate these barriers into public health and national health intervention plans to minimize public health costs and the burden of comorbidities and enhance patient outcomes.

References

Antonelli, D. and Taurino, T. (2010), "Application of a patient flow model to a surgery department", *2010 IEEE Workshop on Health Care Management (WHCM) [Internet]*, *Venice, Italy*, *IEEE*, pp. 1-6, available at: http://ieeexplore.ieee.org/document/5441247/

Asensio, J.A., Petrone, P., Alonso, A., *et al.* (2015), "Contemporary wars and their contributions to vascular injury management", *European Journal of Trauma and Emergency Surgery*, Vol. 41 No. 2, pp. 129-142.

Báscolo, E., Houghton, N. and del Riego, A. (2018), "Types of health systems reforms in Latin America and results in health access and coverage", *Revista Panamericana de Salud Publica/Pan American Journal of Public Health*, Vol. 42, p. e126.

Becker, D.M., Tafoya, C.A., Becker, S.L., Kruger, G.H., Tafoya, M.J. and Becker, T.K. (2016), "The use of portable ultrasound devices in low- and middle-income countries: a systematic review of the literature", *Tropical Medicine & International Health*, Vol. 21 No. 3, pp. 294-311.

Botero, J.D. and Jaramillo, J.B. (2023), "Epidemiología De los desórdenes venosos crónicos".

Buitrago, J., Cano, A.F., Cano, L.F., Cardona, J.A., Machado, F.A. and Valencia, M. (2011), "Factores de riesgo y prevalencia de venas varicosas como factor de riesgo de tromboembolismo venoso en pacientes hospitalizados", *Rev. Col. Cir. Vasc*, Vol. 11 No. 2, pp. 43-52.

Caicedo, Y., Gallego, L.M., Clavijo, H.J., Padilla-Londoño, N., Gallego, C.N., Caicedo-Holguín, I., Guzmán-Rodríguez, M., Meléndez-Lugo, J.J., García, A.F., Salcedo, A.E., Parra, M.W., Rodríguez-Holguín, F. and Ordoñez, C.A. (2022), "Resuscitative endovascular balloon occlusion of the aorta in civilian pre-hospital care: a systematic review of the literature", *European Journal of Medical Research*, Vol. 27 No. 1, p. 202.

Calderón, C.A.A., Botero, J.C., Bolaños, J.O. and Martínez, R.R. (2011), "Sistema de salud en Colombia: 20 años de logros y problemas", *Ciência & Saúde Coletiva*, Vol. 16 No. 6, pp. 2817-2828.

Camargo, J., Perez, L.E., Franco, C., Rodríguez, E.S. and Anchez, W. (2014), "Panther strategy': military trauma in Colombia", *Rev Colomb Cir*, Vol. 29 No. 4, pp. 293-304.

Cardona, S., Garcia, D.A.E. and Montoya, J.A. (2021), "Isolation typology through accessibility measures considering rurality and armed conflict, a case study in Caldas, Colombia", Rural and Remote Health, RRH, available at: www.rrh.org.au/journal/article/6128

Cataño Bedoya, J.U., Duque Botero, J., Naranjo González, C.A., Rúa Molina, D.C., Rosique Gracia, J., García Pineda, A.F., Gómez Isaza, L.F., Cardona-Arias, J.A., Caro, M.A., Bedoya Berrío, G. and Pizano Ramírez, N.D. (2015), "Prevalencia de factores de riesgo cardiovascular en indígenas Embera-chamí de cristianía (jardín), Antioquia", *Iatreia*, Vol. 28 No. 1, pp. 5-16.

Charles, R., Hood, B., Derosier, J.M., Gosbee, J.W., Li, Y., Caird, M.S., *et al.* (2016), "How to perform a root cause analysis for workup and future prevention of medical errors: a review", *Patient Safety in Surgery*, Vol. 10 No. 1, p. 20.

Cofano, F., di Perna, G., Bozzaro, M., Longo, A., Marengo, N., Zenga, F., *et al.* (2021), "Augmented reality in medical practice: from spine surgery to remote assistance", *Frontiers in Surgery*, Vol. 8, p. 657901.

Correa Posada, M.O., Contreras Correa, L.M. and García Vélez, J.F. (2022), "Factors associated with chronic venous disease: study in 1,136 patients treated for varicose veins of the lower limbs in a specialized clinic", *J Vasc Bras*, Vol. 21, p. e20220051.

Dalton, M.K., Remick, K.N., Mathias, M., Trinh, Q.-D., Cooper, Z., Elster, E.A., *et al.* (2022), "Analysis of surgical volume in military medical treatment facilities and clinical combat readiness of US military surgeons", *JAMA Surgery*, Vol. 157 No. 1, p. 43.

Departamento administrativo nacional De estadística – DANE, Oviedo Arango, J.D., Martínez, C., Vargas, L., Quinchua, J., Valencia, R., de la Ossa, M.F., Mazorra, L. and Chaux, F. (2022), "Departamento administrativo nacional De estadística – DANE, pobreza monetaria", [Internet], available at: www.dane.gov.co/index.php/estadisticas-por-tema/pobreza-y-condiciones-de-vida/pobreza-monetaria

Daniels, J.P. (2016), "Helping Colombia's landmine survivors", *Lancet (London, England)*, Vol. 387 No. 10033, pp. 2079-2080.

Dolan, M. (2020), "Radical responses: architects and architecture in urban development as a response to violence in Medellín, Colombia", *Space and Culture*, Vol. 23 No. 2, pp. 106-128.

Elster, E.A., Butler, F.K. and Rasmussen, T.E. (2013), "Implications of combat casualty care for mass casualty events", *JAMA*, Vol. 310 No. 5, p. 475.

Escobar, M.F., Henao, J.F., Prieto, D., Echavarria, M.P., Gallego, J.C., Nasner, D., *et al.* (2021), "Teleconsultation for outpatient care of patients during the covid-19 pandemic at a university hospital in Colombia", *International Journal of Medical Informatics*, Vol. 155, p. 104589.

García, A.M., Gutiérrez, J., Villamil, E., Sánchez, W., Villarreal, L., Lozada-Martinez, I.D., Picón-Jaimes, Y.A., Pérez, M. and Cabrera-Vargas, L.F. (2022), "Predictors for limb amputation in war vascular trauma: a 20-years retrospective analysis from the Colombian armed conflict", *American Journal of Surgery*, 2022;S0002-9610(22)00633-X.

García, G., Calle, W., Ramírez, W., Díaz, C., Rene, T., Uribe, J., Tobon, I., Mejía, F. and Patiño, J. (2008), "Prevalencia del aneurisma aórtico abdominal en el área urbana de medellín, Colombia", *Scielo*, Vol. 21, pp. s16-s16.

Hall, A.B., Qureshi, I., Gurney, J.M., Shackelford, S., Taylor, J., Mahoney, C., *et al.* (2021), "Clinical utilization of deployed military surgeons", *Journal of Trauma and Acute Care Surgery*, Vol. 91 No. 2S, pp. S256-S260.

Harris, R.D. and Marks, W.M. (2009), "Compact ultrasound for improving maternal and perinatal care in low-resource settings: review of the potential benefits, implementation challenges, and public health issues", *Journal of Ultrasound in Medicine*, Vol. 28 No. 8, pp. 1067-1076.

Hayes, R.H. and Wheelwright, S.C. (2021), "The dynamics of process-product life cycles", Harvard Business Review [Internet]. 1979 Mar 1 [cited 2021 Oct 14], available at: https://hbr.org/1979/03/the-dynamics-of-process-product-life-cycles

Holt, D.B., Hueman, M.T., Jaffin, J., Sanchez, M., Hamilton, M.A., Mabry, C.D., *et al.* (2021), "Clinical readiness program: refocusing the military health system", *Military Medicine*, Vol. 186 No. Supplement_1, pp. 32-39.

Isacson, A. (2023), "The human rights landscape in Colombia", p. 24.

Kaplan, R.S. and Norton, D.P. (2008), "Mastering the management system", *Harvard Business Review*, available at: https://hbr.org/2008/01/mastering-the-management-system

Karthikesalingam, A., Holt, P.J., Vidal-Diez, A., Ozdemir, B.A., Poloniecki, J.D., Hinchliffe, R.J. and Thompson, M.M. (2014), "Mortality from ruptured abdominal aortic aneurysms: clinical lessons from a comparison of outcomes in England and the USA", *The Lancet*, Vol. 383 No. 9921, p. 963.

Kühnl, A., Erk, A., Trenner, M., Salvermoser, M., Schmid, V. and Eckstein, H.H. (2017), "Incidence, treatment and mortality in patients with abdominal aortic aneurysms", *Dtsch Arztebl Int*, Vol. 114 Nos 22/23, pp. 391-398.

La República (2022), "Hay 2.2 millones de migrantes venezolanos viviendo en Colombia y 24% en bogotá [internet]", available at: www.larepublica.co/economia/hay-2-2-millones-de-migrantes-venezolanos-viviendo-en-colombia-y-24-en-bogota-3363654#:~:text=De%20acuerdo%20con%20cifras%20del,los%20ha%20recibido%20la%20capital

Lacy, A.M., Bravo, R., Otero-Piñeiro, A.M., Pena, R., De Lacy, F.B., Menchaca, R., *et al.* (2019), "5G-assisted telementored surgery", *British Journal of Surgery*, Vol. 106 No. 12, p. 1576.

Li, X., Zhao, G., Zhang, J., Duan, Z. and Xin, S. (2013), "Prevalence and trends of the abdominal aortic aneurysms epidemic in general population–a meta-analysis", *PLoS ONE*, Vol. 8 No. 12, p. e81260.

Liu, H., Zhang, L., Ping, Y. and Wang, L. (2020), "Failure mode and effects analysis for proactive healthcare risk evaluation: a systematic literature review", *Journal of Evaluation in Clinical Practice*, Vol. 26 No. 4, pp. 1320-1337.

Londoño, E. and Molano, P. (2015), "Are Colombia's reforms enough for a health-care system in crisis?", *The Lancet*, Vol. 385 No. 9981, p. 1943.

Marriott, A.E., Sjoberg, H., Tyrer, H., Gamble, J., Murphy, E., Archer, J., *et al.* (2018), "Validation of ultrasound bioimaging to predict worm burden and treatment efficacy in preclinical Filariasis drug screening models", *Scientific Reports*, Vol. 8 No. 1, p. 5910.

Memos, V.A., Minopoulos, G. and Psannis, K.E. (2023), "The impact of IoT and 5G technology in telesurgery: benefits & limitations", p. 3.

Ministerio de Agricultura y Desarrollo Rural (2021), "El desarrollo rural en cifras: 1. Principales caracteristicas sociales de la poblacion rural en Colombia", available at: www.agronet.gov.co/agroclima/Documents/cartilla.pdf (accessed Jan 28 2023).

Mogollón-Pérez, A.S. and Vázquez, M.L. (2008), "Factores que inciden en el acceso de la población desplazada a las instituciones prestadoras de servicios de salud en Colombia", *Cadernos de Saúde Pública*, Vol. 24 No. 4, pp. 745-754.

Offstein, N. and Aristizábal, C. (2003), "An historical review and analysis of colombian guerrilla movements: FARC, ELN and EPL", *Revista Desarrollo y Sociedad*, Vol. 52 No. 52, pp. 99-142.

Paudel, P. and Bhattarai, A. (2023), "5G telecommunication technology: history, overview, requirements and use case scenario in context of Nepal", p. 5.

Porta, C.R., Robins, R., Eastridge, B., Holcomb, J., Schreiber, M. and Martin, M. (2014), "The hidden war: humanitarian surgery in a combat zone", *The American Journal of Surgery*, Vol. 207 No. 5, pp. 766-772.

Ramirez, P. and Norman, D. (2009), *Guías Colombianas Para el Diagnóstico y el Manejo de Los Desórdenes Crónicos de Las Venas*, Guadalupe SA, Bogotá DC.

Rasmussen, T.E., Clouse, W.D., Peck, M.A., *et al.* (2008), "Development and implementation of endovascular capabilities in wartime", *Journal of Trauma: Injury, Infection & Critical Care*, Vol. 64 No. 5, pp. 1169-1176.

Ríos, J. (2018), "From war to peace: understanding the end of the armed conflict in Colombia", *Rationality and Society*, Vol. 30 No. 4, pp. 463-490.

Romero, T. (2022), "Percentage of income held by the richest 20 percent of the population in Colombia from 2010 to 2020", World Bank, available at: www.statista.com/statistics/1075279/colombia-income-inequality/ (accessed 12 July).

Sharma, G., Wong, D., Arnaoutakis, D.J., Shah, S.K., O'Brien, A., Ashley, S.W., *et al.* (2017), "Systematic identification and management of barriers to vascular surgery patient discharge time of day", *Journal of Vascular Surgery*, Vol. 65 No. 1, pp. 172-178.

Stewart, K.A., Navarro, S.M., Kambala, S., Tan, G., Poondla, R., Lederman, S., *et al.* (2020), "Trends in ultrasound use in low and Middle income countries: a systematic review", *International Journal of Maternal and Child Health and AIDS (IJMA)*, Vol. 9 No. 1, pp. 103-120.

Swink, M., Melnyk, S.A. and Hartley, J.L. (2020), *Managing Operations: Across the Supply Chain*, 4th international student edition, The McGraw-Hill education series operations and decision sciences, McGraw-Hill Education, New York, NY, p. 627.

The Economist (2015), "Colombia: the promise of peace", [Internet][cited 2022 Apr 5], available at: www.economist.com/graphic-detail/2015/11/02/colombia-the-promise-of-peace

Toscano, M., Marini, T.J., Drennan, K., Baran, T.M., Kan, J., Garra, B., *et al.* (2021), "Testing telediagnostic obstetric ultrasound in Peru: a new horizon in expanding access to prenatal ultrasound", *BMC Pregnancy and Childbirth*, Vol. 21 No. 1, p. 328.

Tsukanov, Y. and Tsukanov, A. (2017), "Diagnosis and treatment of situational great saphenous vein reflux in daily medical practice", *Phlebolymphology*, Vol. 24, p. 144.

Turner, C.D.A., Lockey, D.J. and Rehn, M. (2016), "Pre-hospital management of mass casualty civilian shootings: a systematic literature review", *Critical Care*, Vol. 20 No. 1, p. 362.

Ulloa Dominguez, J., Lopez, P.F., Ulloa, J.H., Salazar, J. and Penagos, A. (2018), "Prevalence of hypothyroidism in adults with chronic venous insufficiency", *Acta Phlebol*, Vol. 19, p. 1124.

Ulloa, J.H., Comerota, A., Figueroa, V. and Cifuentes, S. (2021), "Great saphenous vein occlusion rates after combined treatment with laser and foam sclerotherapy", *Journal of Vascular Surgery: Venous and Lymphatic Disorders*, Vol. 9 No. 6, pp. 1437-1442.

van der Putten, K., Anderson, M.B. and van Geenen, R.C. (2022), "Looking through the lens: the reality of telesurgical support with interactive technology using Microsoft's HoloLens 2", *Case Reports in Orthopedics*, Vol. 2022, pp. 1-5.

Walley, P. (2003), "Designing the accident and emergency system: lessons from manufacturing", *Emergency Medicine Journal*, Vol. 20 No. 2, pp. 126-130.

Yardley, S., Teunissen, P.W. and Dornan, T. (2012), "Experiential learning: transforming theory into practice", *Medical Teacher*, Vol. 34 No. 2, pp. 161-164.

Further reading

García Pineda, A.F. (2023), "Un estudio bioantropológico de los desórdenes venosos crónicos y sus factores de riesgo en el suroeste de Antioquia: población urbana de jardín y resguardo indígena de karmata rúa (cristianía)".

Corresponding author

Oscar Y. Moreno Rocha can be contacted at: oscar.md@icloud.com

Executive summary and implications for managers and executives

Access to health care is limited due to the barriers related to universal coverage and timeliness in novel emergencies. The execution of a medical deployment, assessment and response in peripheral areas, conflict zones and other public health crises usually requires a faster response. This can only be achieved by developing novel strategies and enhancing them for better outcomes. Limited access to vascular medicine and other specialties can increase the burden of diseases and related complications. To improve the process for assessing VS pathologies in areas without proper access to vascular consult and conflict zones, we developed and implemented a flexible flow-model operating plan from other fields different from medicine to enhance the mobile screening process of vascular patients. The process was assessed based on the medical methodologies of "Failure mode and effects analysis (FMEA)" before deployment and "Control Chart and root cause analysis (RCA)" once it began. We tested this methodology in a controlled setting with 140 patients simulating a deployment in a remote area. We incorporated the recommendations and improvements of the original methods and summarized them in this article. Our operation methodology includes how we developed, assessed and enhanced this novel tool in five stages: strategy development and adjustment; translation of the strategy into a real-world setting; operation logistical planning; operation conduction and monitoring; strategy analysis and adoption. Modifications were made using FMEA and RCA recommendations for health care and the product-process matrix from business theory. This tool can be implemented for 100–300 patient assessments and modified to fulfill the required demand. It demonstrated excellent efficiency in real life. This strategic plan for assessing vascular diseases can be implemented in remote areas with difficult access to vascular surgery (VS) evaluation and possibly extrapolated to conflict zones that require complex diagnostic and treatment interventions. It is crucial to assess the most significant number of patients in remote areas and treat them according to their triage designation. With the use of MUVA, we were able to efficiently determine, classify and redirect patients with positive findings to therapeutic interventions in remote areas with a high-quality assessment.