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The Vascular Society for Great Britain and Ireland

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The Vascular Society of Great Britain and Ireland (VSGBI) is the pre-eminent organisation in the country promoting vascular health by supporting and furthering excellence in education, training and scientific research.

The Society represents and provides professional support for over 600 members, including vascular surgeons, vascular radiologists and others involved in independent vascular practices in Great Britain and Ireland.

The Society focuses on non-cardiac vascular disease, including diseases of the aorta, peripheral arteries, veins and lymphatic. Vascular specialists are trained in the diagnosis and management of conditions affecting all parts of the vascular system.

The VSGBI is a charitable organisation funded by members subscriptions, an annual scientific meeting, grants and donations. It has a professional structure including a permanent Secretariat, Executive Officers and Council elected by Members.

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Editor's foreword

Welcome to the February 2026 edition of the *JVSGBI*.

We have two editorials in this issue, the first editorial is the third of a series by Long and co-authors outlining approaches to ensure mentorship is efficient, effective and meaningful with specific reference to the recently launched VSGBI mentorship programme for newly appointed vascular surgical consultants. The second editorial by Ravindhran & Thakker describes the various ways machine learning and artificial intelligence can substantially input to the care and outcome of patients with peripheral arterial disease.

We present three original research studies. Duff and colleagues describe a modified Delphi study to direct the development of a rehab programme of CLTI patients following revascularisation. Atha and colleagues present the results of a UK survey of predominantly vascular surgeons and anaesthetists assessing views and practice regarding tranexamic acid in vascular surgery and enthusiasm for a future randomised controlled trial. Finally, Tokede and Kreckler present a study assessing the value of utilising pre-existing cross sectional imaging to improve the efficiency of the NHS Abdominal Aortic Aneurysm Screening Programme (NAAASP).

Our first published Quality Improvement Project by Al-Kassar looks at improving documentation in a hub-and-spoke system with potential patient benefits. We also present an interesting protocol by Lim Way Wern and colleagues for a systematic review designed to compare outcomes between wounds which are left to heal by secondary intention or are closed (primarily or delayed primary).

Three case reports are also presented. Harker and colleagues present 3 cases of lesions referred as arteriovenous malformations which ultimately were found to be more serious lesions. Abdelmalak and colleagues present a case of iliac stent infection requiring surgical revision, and Chikhal and colleagues present the surgical management of a true radial artery aneurysm.

Finally we have updates from the *JVSGBI's* affiliated societies.

I personally would like to thank the editorial team for their ongoing commitment and support, reviewers for their time and insightful comments, and authors for there continued submission of articles for publication. Please continue to submit your articles for publication via email to: editorialoffice@jvsgbi.com.

Ian Chetter
Editor in Chief JVSGBI
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EDITORIAL

Making mentorship meaningful: a closer look at the mentoring journey

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Introduction

Previous editorials set out the rationale for introducing mentorship within UK vascular surgery and provided a high-level overview of what to expect from the VSGBI mentorship programme.[1,2] As the first cohort begins its mentoring journey, this issue turns its attention to the mentoring relationship itself: how it develops, what sustains it and how it delivers meaningful professional growth.

Some of you will have heard Professor David Clutterbuck, keynote speaker at the recent VSGBI Annual Meeting in Hull, deliver a thought-provoking presentation on developmental mentoring. He describes mentoring relationships as evolving through five phases: (1) rapport building; (2) direction setting; (3) progress making; (4) winding up; and (5) moving on.[3] This provides a practical framework that underpins the VSGBI approach to mentorship. Understanding these phases allows mentors and mentees to engage intentionally, recognising that effective mentorship evolves over time.

Phase 1: Rapport building

Effective mentorship begins with trust, rapport and clear goals. Without these foundations the relationship cannot progress beyond superficial exchange (see Box).

Early meetings typically explore professional background, career trajectory, aspirations and motivations for joining the programme, helping to clarify shared purpose and expectations. Establishing this alignment may take time and goals may evolve as careers develop.

Within vascular surgery, psychological safety is essential. The specialty is technically complex and carries significant responsibility and surgeons must feel able to discuss uncertainty, complications, leadership challenges and career transitions openly, without fear of judgement. Investing in trust and clarity at the outset lays the foundation for productive goal-focused partnerships and determines the level of honesty, insight and growth that the mentoring journey can achieve.

Box Key elements for rapport building in mentorship

- Mutual interest, trust and psychological safety
- Mutual respect and positive regard
- Broad agreement on the purpose of the relationship
- Alignment of expectations about roles and behaviours

As described in *Mentoring in Action*[3]

Phase 2: Direction setting

Direction setting involves establishing what the relationship intends to achieve and how time together will be structured. Goals are often initially broad – leadership development, academic progression, resilience – before becoming more defined. For some vascular surgeons this may involve preparing for consultant transition, developing operative confidence, shaping an academic portfolio or taking on service leadership responsibilities. For others, the focus may be resilience, professional identity or achieving a better work–life balance. As circumstances change, aims may be refined accordingly.

Phase 3: Progress making

The progression phase represents the most intensive period of learning in a mentoring

Key words: early-career consultants, mentorship, professional development

relationship. After two or three sessions focused on building rapport and aligning expectations, mentors and mentees move into this stage to make measurable progress. Productive discussions typically involve agreeing the focus of the meeting, exploring issues from the mentee's perspective, clarifying context, challenging assumptions, analysing and identifying realistic next steps.

Mentors may adopt different roles depending on the context; at times as a professional friend providing confidential space, at others a sounding board, reflector or guide. This flexibility enables the relationship to respond to evolving developmental needs.

A core principle of progression is providing space for reflection. In vascular practice, a reflective approach is particularly valuable; it allows mentees to examine decision-making, navigate setbacks and build professional confidence. The mentor's role is not to provide solutions but to support the mentee in developing insight, judgement and autonomy.

Phase 4: Winding up

The winding up phase provides an opportunity to consolidate learning, acknowledge growth and express mutual appreciation. Mentor and mentee review what has been achieved, identifying changes in capability, confidence, leadership behaviour or career direction. Acknowledging these developments highlights their significance and reinforces the value of the time invested in the mentoring relationship. Concluding deliberately and thoughtfully not only reflects professionalism but ensures the mentoring relationship ends with clarity and purpose rather than fading without direction.

Phase 5: Moving on

The final phase recognises that, while formal mentoring concludes, professional relationships often evolve rather than disappear. Some partnerships transition into collegiality. In time, mentees may themselves become mentors, strengthening a sustainable culture of support within UK vascular surgery. Moving on symbolises growth. The mentee has progressed beyond the starting point of the relationship and the mentoring has fulfilled its purpose.

As outlined in earlier editorials,[1,2] the VSGBI mentorship programme aims to strengthen leadership, resilience and professional development within vascular surgery. Professor Clutterbuck's five-phase framework provides a clear way to understand this approach.[3] Rapport enables trust. Direction provides clarity. Progress generates growth. Winding up consolidates achievement. Moving on signals maturity.

When mentors and mentees engage intentionally across each phase, mentorship becomes more than guidance; it becomes a deliberate investment in leadership and in the future of the vascular specialty.

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EDITORIAL

The utility of machine learning in the management of patients with peripheral arterial disease

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Introduction

Machine learning (ML) is moving decisively from concept to clinic-adjacent evaluation in vascular medicine. Peripheral arterial disease (PAD) has become a major focus for machine learning because it is clinically heterogeneous and carries a high health and economic burden, making it well suited to data driven approaches for earlier detection and personalised risk assessment. The core promise remains unchanged: algorithms that learn patterns across multimodal data, notes, vital signs, blood results, ultrasound or duplex waveforms, CT and MR angiography, intravascular imaging, prescriptions and longitudinal outcomes can help detect disease earlier, stratify risk more reliably and match treatment to patient and lesion characteristics. The crucial question for vascular surgeons is where that promise stands today. Across diagnostics, risk stratification and outcome prediction, AI/ML is best regarded as a maturing adjunct whose best-performing tools are either in retrospective or quasi-prospective evaluation, with a small but growing body of external validation. The field is now constrained less by raw model accuracy and more by generalisability, clinical integration, explainability and governance.

Diagnostics

Diagnostic applications have produced some of the most tangible early gains. Electronic health record phenotyping and natural language processing have the potential to flag probable PAD from codes, medication patterns, laboratories and free-text notes with performance that is sufficient to support targeted ankle–brachial pressure index (ABPI) or vascular laboratory testing in primary care and diabetes clinics.[1–3] Real-world implementation work has started to define how such models can be integrated into care pathways; qualitative and mixed-methods studies emphasise workflow alignment, clinician trust and equity monitoring as prerequisites for sustained use.[4,5] In the vascular laboratory, algorithms to classify continuous wave Doppler and plethysmography waveforms are increasingly accurate in laboratory settings and can reduce inter-operator variability, although prospective evidence of the impact on diagnostic accuracy or throughput remains limited.[6–9] In imaging, deep learning for CT angiographic segmentation and stenosis quantification continues to advance quickly, with several groups reporting automated arterial tree segmentation, calcium scoring, runoff quantification and lesion severity classification, particularly in the femoro-popliteal and infrapopliteal beds.[10–14] These systems show high agreement with expert readers on retrospective datasets, but cross-scanner and cross-centre robustness and prospective clinical utility are still in the process of being established.

Intravascular imaging is benefiting from ML originally developed for coronaries: plaque component detection and calcium quantification on intravascular ultrasound and optical coherence tomography, and early peripheral applications suggest feasibility for reproducible measurements that could guide vessel preparation and device selection. However, PAD-specific clinical validation and device-agnostic performance remain works in progress.[15,16] Outside of imaging suites, photoplethysmography captured by smartphones and wearable devices has shown proof-of-concept for PAD screening, but large-scale prospective studies in target populations, with confirmatory testing and cost-effectiveness

Key words: machine learning, peripheral arterial disease, artificial intelligence, algorithms

analyses, are still awaited before routine clinical adoption can be recommended.[8,17,18] Taken together, diagnostic AI for PAD is moving from promising retrospective accuracy to early-stage clinical evaluation. In the near term, adoption is best directed towards tasks with outputs that are directly verifiable at the point of care such as waveform classification, stenosis measurements and structured report extraction, while simultaneously building the implementation evidence base.

Risk stratification

Risk stratification for both major adverse cardiovascular events and major adverse limb events is central to PAD care, and this is an area where ML has achieved clinically meaningful performance on large registries and multi-institutional datasets. Recent studies using the Vascular Quality Initiative and other consortia demonstrate that ML can estimate 30-day and long-term risks of major adverse limb events, amputation, reintervention, pour wound healing and major adverse cardiovascular events with very good discrimination and improved calibration relative to traditional scores.[19] Multicentre registry analyses have trained and tested models to predict short and long-term adverse outcomes after endovascular intervention, showing reasonable performance and calibration. However, they also highlight the need for external validation and clinically actionable risk outputs. Similar models for bypass outcomes show promise, but generalisability remains challenging due to device and conduit-specific heterogeneity, centre effects, and missingness in key variables (e.g., runoff).[20–25] At this stage, selective deployment of validated models to inform shared decision-making and surveillance planning is appropriate provided calibration is satisfactory, probabilities are communicated transparently and local performance has been verified. Subgroup performance should be reported and shown to be acceptable in view of well-established disparities in PAD presentation and outcomes.

Early and delayed outcome prediction

Beyond risk stratification, AI/ML is increasingly used for granular outcome prediction tied to procedural planning and follow-up. Peri-procedural complications such as contrast-associated kidney injury, bleeding and access site problems have been modelled with encouraging retrospective performance.[26] Looking further out, lesion-specific models that incorporate CTA features, duplex metrics and lesion morphology are being developed to predict primary patency and target lesion revascularisation, with several reports demonstrating strong internal performance but mixed external validation.[27,28] Prediction of wound healing, a particularly relevant domain for chronic limb threatening ischaemia and multidisciplinary limb salvage teams, has been studied using a mix of clinical features, perfusion measurements and wound images. While multiple groups report models with good discrimination, the literature remains fragmented by small sample sizes, heterogeneous definitions of healing and limited external testing. In the absence of interpretable models and standardised endpoints, routine use is not yet justified.[29,30] There is an emerging consensus that prediction models deliver greatest value when coupled to modifiable actions – for example, earlier duplex surveillance in patients at heightened restenosis risk and targeted optimisation of perfusion and infection control when healing probability is low, with prospective impact evaluations now a priority.

Current work around the world

Globally, research is converging on three practical directions. First, registry-linked modelling on major analogous datasets is yielding models that can be externally validated and benchmarked across systems, with increasing attention to calibration, decision-curve analysis and net benefit.[31] Second, imaging AI is being standardised, with communities working on shared tasks for CTA segmentation and lesion scoring to improve reproducibility across vendors and scanners, and on explainable overlays that let clinicians see which image regions drive a classification. Third, privacy-preserving training such as federated learning is being piloted to overcome data sharing barriers while improving model generalisability across diverse populations and devices.[32] Notably, in comparative evaluations, ML systems have outperformed clinicians, demonstrating higher discrimination and lower prediction error than expert assessment or conventional risk scores, moving the field a step closer to reliable adjunctive decision support at the point of care.[33] Operationally, clinical deployment is best underpinned by multicentre validation, adoption of standardised data models and terminology to streamline collaboration and, when feasible, federated methods to promote diversity and equity.

Explainable AI

In clinical decision support, explainability means making a model's predictions transparent and clinically interpretable, both at the individual level (why this output was produced for this patient) and at the broader level (how the system behaves overall and which factors most influence its outputs). Practically, this allows us to see which variables or image regions most influenced a risk estimate, judge whether the rationale aligns with the patient's presentation, and decide when to accept, qualify or override the recommendation.[34] Explainability is now recognised as a safety requirement rather than a research feature. It underpins safe deployment by enabling clinicians to verify outputs, identify potential model errors and maintain accountability in decision-making. For structured (tabular) clinical prediction models, local explanations such as SHAP value summaries, Local Interpretable Model-agnostic Explanations (LIME) plots[35] and global feature importance analyses have become standard practice in recent high-quality studies and clinical pilots, enabling clinicians to understand why the model assigns a high risk label to a particular patient.[36] For imaging, saliency maps and attention overlays have matured to the point that they can highlight stenotic segments or plaque components that informed the output. Tools intended for bedside use should display their confidence and calibration characteristics, provide example-

level explanations and defer to interpretable models when they perform equivalently.[31] It is also recommended that ongoing performance monitoring be in place to detect drift and inequities. A 'near-miss' reporting culture around AI recommendations, akin to pharmacovigilance, is an emerging recommendation more broadly, so failures are learned from and shared.[37]

AI governance

Regulatory and institutional governance has advanced materially in the past two years. This reflects a shift from voluntary principles to enforceable mechanisms for AI assurance and post-market oversight. The US FDA finalised guidance on Predetermined Change Control Plans for AI-enabled device software functions in late 2024, clarifying how iterative model updates can be managed within an approved framework, and subsequently integrated that guidance into its AI/ML SaMD (Software as a medical device) resources in 2025.[38] These updates clarify regulator expectations for adaptive algorithms and continuous learning systems, which have historically faced uncertainty under fixed-approval pathways. Internationally and in the UK, Good Machine Learning Practice principles jointly articulated by regulators provide direction on data management, training/validation and human factors. Together, these principles emphasise transparency, reproducibility and clinician accountability across the AI lifecycle. At the institutional level, it is recommended that model deployment be overseen by multidisciplinary committees including vascular surgery, data science, ethics, legal, IT security and patient representatives. Such committees serve as local assurance bodies, ensuring that governance responsibilities are shared rather than delegated solely to data science teams. Documentation such as model cards should specify intended use, data provenance, performance across subgroups, known failure modes and update cadence. Explicit traceability between data, model versions and deployment environments should be maintained to support audit and incident review. For continuously learning systems, versioning, change control and re-approval triggers are essential so that the tool in clinic matches the tool that was validated. It is also recommended that local monitoring assess equity, alert burden and clinical workflow effects, with the authority to pause or retire models when harms outweigh benefits.[39,40] Embedding these practices establishes a feedback loop between technical governance and clinical safety, aligning local oversight with emerging regulatory expectations.

Adjunct role in practice

Clinician expertise remains central, and the most appropriate framing today is that AI/ML is an adjunct. This framing reinforces clinical accountability and aligns with current regulatory guidance that mandates human oversight for all high-risk AI systems. In diagnostics, it is recommended that algorithms pre-screen and double-check while examination, bedside Doppler and ABPI/TBPI remain foundational. Early evidence suggests that such hybrid workflows preserve diagnostic accuracy while reducing clinician workload and variability. Beyond specialist settings, dynamic ML models embedded in community and primary care records have shown promise in identifying high risk PAD patients in real time, enabling prioritisation for assessment and treatment.[41] In shared decision-making, individualised risk estimates expressed as natural frequencies and simple visuals can help patients understand trade-offs between limb salvage strategies, surveillance intensity and the burden of therapy. Presenting outputs in interpretable formats also helps maintain informed consent and patient trust in AI-supported decisions. In stratification, consistent risk labels across teams, vascular surgery, podiatry, wound care, cardiology, can coordinate care so that high-risk patients receive timely interventions. Interoperability and shared data standards are key to ensuring that such risk stratification remains consistent across systems and institutions. Across the continuum, AI/ML can reinforce risk factor management by identifying patients likely to benefit from statin adherence, supervised exercise therapy, smoking cessation support, glycaemic optimisation and foot care education; it is recommended that these digital nudges be embedded within clinician-led pathways to ensure accountability and equity. In this configuration, AI functions as a precision-enabling layer within clinician-led pathways, amplifying preventive care rather than displacing professional judgement.

Pitfalls: black box, equity, and overfitting

The most common pitfalls are now well documented. Black box models may latch onto spurious correlates such as scanner signatures, site effects or documentation quirks, which collapse when deployed elsewhere.[42] Overfitting to single-centre datasets remains common, as does inadvertent data leakage that inflates performance.[43] Equity concerns are prominent because PAD disproportionately affects patients with diabetes, chronic kidney disease and socioeconomic disadvantage; subgroup performance gaps can widen existing disparities. For these reasons, it is recommended that studies prespecify cohorts, strictly separate training and testing by patient and time, and perform external validation across sites, devices and populations. Calibration should be reported alongside discrimination, and decision-curve analyses should make net benefit explicit. Bias mitigation strategies, reweighting, balanced sampling, threshold adjustment and fairness-aware evaluation are recommended and should be transparently reported.[44] Automation bias and deskilling are human factor risks; it is recommended that interfaces display rationale and uncertainty and that clinicians stay in the loop for interpretation and override.[45] Embedding these safeguards converts technical validation into operational safety, ensuring models remain trustworthy under real-world conditions.

Reporting and appraisal guidelines

Methodological rigour is improving, supported by new and updated guidance. Collectively, these frameworks mark a shift from ad-hoc

KEY MESSAGES

- Machine learning has the potential to support management of peripheral arterial disease by flagging patients at risk, standardising diagnostic interpretation and providing individualised estimates of limb and cardiovascular outcomes. The most mature tools are adjuncts that fit within existing workflows. Adoption should focus on transparent verifiable outputs that link to clear actions and measurable benefits now.
- Safety and accountability depend on explainability, calibration and continuous monitoring. Tools used clinically should show why a prediction was made, expose uncertainty and perform acceptably across subgroups. Governance is essential: version control, change management, incident reporting and multidisciplinary oversight help detect drift, reduce bias and protect patients and staff alike.
- The next phase should include measured monitored deployment. Priorities include multicentre validation, common data standards, pragmatic impact studies and clinician centred design. Dynamic models in community records can prioritise high risk patients for timely assessment and treatment. When implemented responsibly, these tools have the potential to standardise care, personalise therapy and improve patient experience and outcomes.

study descriptions to structured auditable evidence standards for clinical AI. TRIPOD+AI provides harmonised reporting standards for prediction model studies regardless of whether regression or ML is used.[46] DECIDE-AI outlines how to report early clinical evaluation of AI decision support.[47] The STARD-AI guideline addresses diagnostic accuracy studies using AI.[48] PROBAST+AI updates the risk-of-bias and applicability assessment for prediction models built with regression or ML.[49] For randomised evaluations, CONSORT-AI and SPIRIT-AI remain the standards.[50,51] Within vascular surgery, uptake of these frameworks by authors, reviewers and editors will promote faster translation by strengthening reproducibility, comparability and clinical relevance. Their consistent adoption will also streamline regulatory submissions and evidence reviews for AI-enabled vascular tools.

Conclusion

The state of AI for PAD in 2026 can be summarised as robust feasibility with islands of readiness. Diagnostic support tools for waveform interpretation and CTA quantification are technically mature and entering early clinical evaluation, with adoption recommended where outputs are transparent and verifiable. Risk stratification for major adverse limb events, major adverse cardiac events, amputation and reintervention is strong enough to support shared decision-making and surveillance planning in many settings, provided that external validation and calibration are documented locally. Prediction of wound healing show promise but require larger, standardised and prospective evaluations before widespread use is recommended. Explainability, governance and equity considerations have moved to the forefront, aided by clearer regulatory pathways and stronger reporting and appraisal guidelines. The immediate trajectory is towards measured monitored deployment with clear assessment of evidence of benefit across outcomes, experience and value. With appropriate safeguards, vascular surgery services are well positioned to introduce targeted AI tools as adjuncts, helping to standardise decisions, personalise treatment and remedy gaps in diagnosis and long-term follow-up for PAD.

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ORIGINAL RESEARCH

Development of a rehabilitation programme for individuals with chronic limb threatening ischaemia post revascularisation (HOPE): a modified Delphi study

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Plain English Summary

Why we undertook the work: Peripheral artery disease (PAD) is a condition that affects blood flow to the legs. Around 236 million people in the world have this condition and this number is likely to rise another 50% by 2045. Chronic limb threatening ischaemia (CLTI) is a serious form of PAD and often requires surgery to improve blood flow. After surgery, however, many individuals still experience poor mobility, pain and serious complications. Some of these complications can lead to amputation and many die within a few years. Rehabilitation is known to benefit people with other conditions, so the aim of this study was to design a rehabilitation programme specifically for individuals with CLTI after they have had surgery. In future we can then see if we can improve the outcomes of those with CLTI.

What we did: Patients, their carers and healthcare professionals took part in a three-round activity called a modified Delphi study. In the first step participants shared ideas about what should be included in a rehabilitation programme. In the second step they rated how important each idea was by either agreeing or disagreeing with them, or by prioritising them. If 70% or more people agreed that the idea was important it was included in the programme. In the final step participants discussed the ideas that had not achieved 70% and then re-voted. The ideas that achieved 70% or over were then added to the programme.

What we found: The group agreed on exercises that should be included in the rehabilitation programme, how often they should be done, where they should take place and how they should be monitored. The group also agreed on education topics that should be included in the programme and how they should be delivered.

What this means: Identifying key components is the first step in designing a rehabilitation programme for individuals with CLTI after they have had surgery. After finalising the programme, the next step is to see how useful and helpful it is in a real-life setting.

Abstract

Background: Peripheral artery disease (PAD) affects over 236 million people globally, with the prevalence continuing to rise. Its most severe form, chronic limb threatening ischaemia (CLTI), affects around 11% of PAD patients and carries high risks of amputation, cardiovascular events and mortality despite revascularisation intervention. Individuals with CLTI often experience poor mobility, frailty and reduced quality of life, yet no structured rehabilitation strategy exists following surgery. This study aimed to develop a novel rehabilitation programme for those with CLTI post revascularisation through a consensus-driven process involving patients, carers and healthcare professionals.

Methods: A multidisciplinary research team conducted a modified Delphi activity between November 2024 and June 2025. The team created the Round 1 questionnaires which were administered online and in paper format and distributed via social media and email networks. Open-ended questions pertaining to rehabilitation, exercise and education aimed to generate a comprehensive list of relevant items. In the Round 2 survey, participants evaluated the inclusion of these items in the rehabilitation programme by rating and prioritising them. Consensus was pre-defined as ≥70% agreement. The final round ran as an online workshop where all findings were presented to participants and items that had not achieved consensus were subjected to further review, discussion and re-evaluation through an online voting process.

Results: 57 participants completed the initial questionnaire. Of these, 20 were healthcare professionals and 37 were individuals with CLTI/carers. Content analysis of responses identified four key domains related to exercise (activities, frequency, location and monitoring) and three domains related to education (content, delivery method and timing). In Round 2, 29 participants responded (13 healthcare professionals and 16 individuals with CLTI/carers), and consensus was achieved on the exercise activities and educational content to be included in the rehabilitation programme. In the online workshop involving nine participants (six healthcare professionals and three individuals with CLTI/carers), consensus was reached on all remaining topics.

Conclusion: The findings informed the design of a novel individualised rehabilitation programme for individuals with CLTI following surgery. Future research is planned to assess the feasibility of this programme.

Key words: Delphi study, rehabilitation, chronic limb threatening ischaemia

Introduction

Peripheral artery disease (PAD) affects over 236 million globally,[1] equating to approximately 20% of individuals aged over 60 in the UK. Already identified as the leading contributor to vascular service demand within secondary care,[2] the prevalence of this condition is projected to increase by 50% by the year 2045.[3] The most severe manifestation of PAD is chronic limb threatening ischaemia (CLTI), characterised by rest pain and gangrene or ulceration lasting more than 2 weeks.[4] Equating to around 11% of PAD cases,[5] CLTI poses a significant threat to both limb viability and overall survival, necessitating prompt revascularisation either through open surgical or endovascular intervention to re-establish perfusion to the lower extremities.[6]

Despite undergoing revascularisation, patients with CLTI remain at considerable risk of adverse outcomes, especially amputation and cardiovascular events. Reported one-year and three-year mortality rates approach 50%, with major adverse cardiovascular events occurring in 42% of cases and amputation rates reaching up to 20% within the same time frames.[6–8] Individuals affected by CLTI typically exhibit severely impaired ambulatory capacity, diminished physical fitness, a predominantly sedentary lifestyle, poor quality of life and clinical features of sarcopenia and frailty, all of which are independently associated with increased morbidity and mortality.[9,10]

In the absence of formal guidance such as a structured secondary prevention strategy following surgical intervention, these clinical trajectories are likely to deteriorate further. Consequently, there is an urgent need to develop and evaluate evidence-based rehabilitation protocols tailored to this high-risk population. While exercise therapy post-revascularisation has demonstrated efficacy in patients with intermittent claudication yielding significant improvements in walking distance and cost-effectiveness,[11–14] its applicability to individuals with CLTI remains uncertain due to no existing evidence. Therefore, the aim of this project was to design a novel rehabilitation programme specifically for individuals with CLTI who have undergone revascularisation surgery. The objectives were to engage people with CLTI, their carers and healthcare professionals who have experience with CLTI in a Delphi exercise and to agree by consensus the structure, content and format of the programme.

Methods

Study design

A Delphi protocol was employed as this technique is widely adopted in health services research to harness the insights of healthcare professionals and individuals with lived experience of health conditions.[15] In the absence of standardised methodology for Delphi studies,[16] this study was characterised as a modified Delphi due to the use of a predefined framework that shaped the initial survey focusing specifically on rehabilitation, exercise and education topics, and the incorporation of an online consensus building workshop. The study was designed adhering to key principles[17] and with an international multidisciplinary scope due to the lack of established CLTI-specific rehabilitation guidance globally.[18]

Based on the research aim, questions pertaining to rehabilitation, exercise and education questions were drafted (JD), refined (SB, YKB and AS) and reviewed (AEH, AH) for Round 1. The open-ended format allowed participants to provide a qualitative response anonymously.[19] Two questionnaires (one for individuals with CLTI/carers and one for healthcare professionals) were created on Jisc Online Surveys,[20] (a secure GDPR-compliant platform) and in paper-based format to enhance accessibility and participation. Pilot testing was conducted prior to dissemination.

The Round 1 survey included a participant information page and required consent to access the questions. A submit button on the final page permitted data collection. Participants could provide an email or postal address to receive the second survey and indicate consent to be contacted regarding the online workshop. The Round 2 survey employed both quantitative and qualitative formats to allow for rating, prioritising and free-text responses.[21] Participants were asked to provide an email or postal address to be contacted regarding the Round 3 workshop and, in line with Round 1, a submit button on the final page permitted data

collection. Round 3 employed an online workshop to facilitate qualitative discussion prior to a final anonymous online vote. This study was conducted and reported in accordance with Conducting and Reporting Delphi Studies (CREDES) guidance to enhance the transparency, methodological rigour and reproducibility of the findings.[22]

Steering group

A multidisciplinary team coordinated the study activity. The research team brings together expertise spanning health psychology, clinical exercise physiology, cardiovascular rehabilitation and vascular surgery, alongside individuals with lived experience. Collectively, the team has extensive experience in the co-design, delivery and evaluation of complex rehabilitation interventions using mixed-methods and consensus-based approaches, including Delphi studies that integrate patient and clinician perspectives.

Public and Patient Involvement and Engagement (PPIE)

As PPIE is paramount in shaping and powering healthcare research,[23,24] it was embedded within this study. A recent James Lind Alliance (JLA) priority setting partnership identified the top 10 research priorities in PAD,[25] which initiated the development of this research.[26] A PPIE advisory group comprising five patients and carers with lived experience of CLTI reviewed the patient questionnaire and provided feedback. This informed several refinements prior to dissemination including rewording items, adding questions and including examples for clarity.

Participants

To optimise the qualitative strength of recommendations or consensus,[27] individuals with CLTI, their carers and healthcare professionals were recruited. Our predefined criteria for participants were individuals living with CLTI, carers of individuals with CLTI and healthcare professionals with experience of CLTI such as vascular surgeons, vascular nurses, physiotherapists, podiatrists, occupational therapists and clinical exercise physiologists.

Sample size

While there is no universally prescribed sample size for Delphi studies,[27] a range of 30–50 participants is generally considered optimal for studies involving homogenous groups.[28] Given the modified nature of this Delphi protocol, a panel size of 30 was targeted, with emphasis placed on achieving balanced representation from both healthcare professionals and individuals affected by CLTI, including carers. No fixed upper limit was imposed; however, the research team agreed to close Round 1 should no novel concepts emerge, in accordance with established guidance.[17]

Recruitment

Two digital recruitment posters were created, one targeting individuals with CLTI/carers and the other healthcare professionals. These were disseminated via social media platforms including PAD support groups on Facebook and LinkedIn. Additionally, the research team used email networks and AS participated in a webinar hosted by an international PAD support group on Facebook to present the research project and encourage participation. Potential participants were able to access the initial questionnaire online via a QR code or hyperlink or, alternatively, to contact JD to request a paper copy.

Data collection and analysis

Data collection took place between November 2024 and June 2025. A three-round modified Delphi protocol was employed to elicit relevant topics, establish consensus and collaboratively inform the design of a rehabilitation programme.

Round 1

The first round (R1) comprised 13 open-ended questions that focused on rehabilitation, exercise and educational needs (see Appendix 1 online at www.jvsgbi.com). The open-ended structure and confidential nature of the questionnaires enabled respondents to elaborate freely, mitigating potential biases associated with group dynamics such as dominance and conformity.[27] The survey opened on 15 November 2024 and the response rate was monitored by JD and SB who had access to the data. The survey closed on 5 February 2025 as the sample size had been achieved and no new data emerged. During this time frame no paper surveys were requested, completed or returned. The online data were exported onto an Excel sheet and analysed by JD who removed duplicates and categorised and sub-categorised free-text responses into relevant domains for the rehabilitation programme.[29] These were subsequently discussed and finalised with the research team (JD, SB, AEH, YKB, AH and AS). This analysis informed the content and structure of the second round (R2) survey. Prior to sending out the R2 survey to participants, the content was checked against the original R1 responses by the research team (JD, SB, AEH, YKB, AH, AS) to ensure no relevant items were missing.

Round 2

The R2 survey comprised structured questions and statements, systematically developed from the domains identified in R1. Consistent with R1, the survey was available online and in paper-based format to ensure broad accessibility. Participants were asked to rate their agreement on the inclusion of elements of the rehabilitation programme via a Likert scale, with response options 1–3 from 'agree' to 'disagree'. Where multiple options had been suggested in R1, all options were presented for prioritising – for example, participants were presented with a list of exercises and asked how often they should be performed. In this example response options were '1–3 times per week', '4–6 times per week' or 'every day'.

The survey opened on 18 February 2025 and the response rate was monitored by JD and SB. In line with guidance,[30,31] reminder emails were sent to non-responders on 7 March 2025 and 17 March 2025 and the survey closed on 29 March 2025 as no new data emerged. The analysis of R2 responses (JD) enabled the

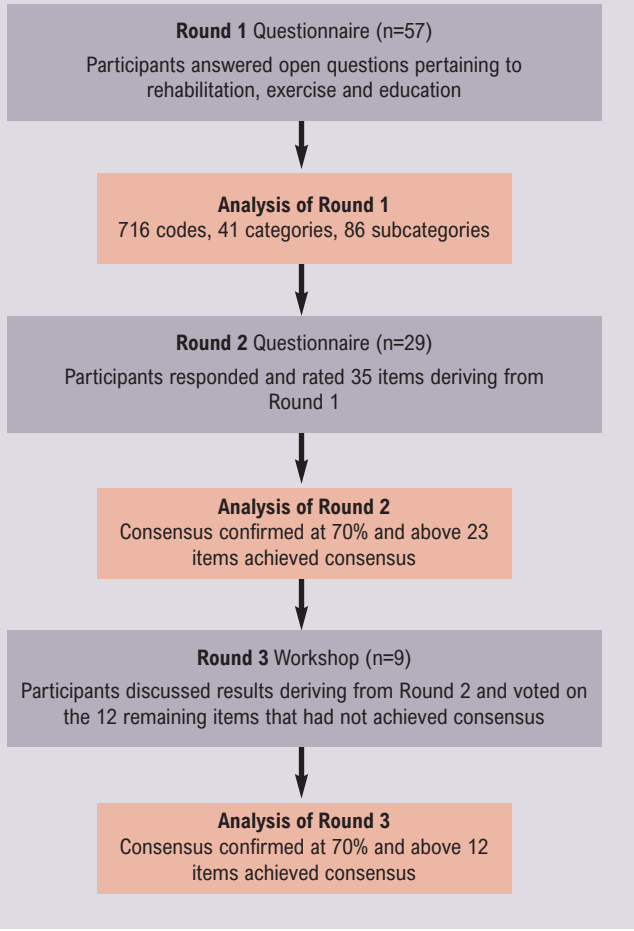
assessment of consensus (level of agreement) among participants.[27] Given the variability in consensus thresholds across Delphi studies,[22] a priori consensus was defined in this study as agreement equal to or exceeding 70%.

Round 3

Consenting participants were emailed the date and time of the workshop and a link to download Microsoft Teams[32] on 16 May. Those who accepted were emailed a workshop agenda, the items to be discussed and a link to join the workshop.

The workshop took place on 27 June 2025 led by the research team with patients, carers and healthcare professionals in attendance. The aim was to confirm consensus from the previous round, explore and quantify levels of agreement on remaining items that had not achieved consensus, and finalise the elements to be included in the rehabilitation programme. At the start of the workshop, previous round results were presented (JD) highlighting items that had not achieved consensus. Participants were then split into two breakout rooms with members of the research team facilitating. The groups reconvened and key points were summarised by the research team. Participants then anonymously agreed or disagreed with seven statements on Jisc. The analysis of the R3 responses (JD) enabled the assessment of consensus (level of agreement) among participants. All items that achieved consensus in R1, R2 and R3 were used to inform the design of the rehabilitation programme.

Figure 1 Overview of the modified Delphi exercise.



Results

An overview of the modified Delphi exercise is shown in Figure 1.

Round 1: Open ended questionnaire

A total of 57 participants completed the initial questionnaire online; no paper surveys were requested. Participants comprised both healthcare professionals and individuals living with CLTI/carers (Table 1). Of these, 20 respondents were healthcare professionals, representing a multidisciplinary cohort that included vascular surgeons, radiologists, academic researchers, physiotherapists and podiatrists. All the healthcare professional participants were based in the UK, with geographical representation spanning diverse regions (both rural and urban) such as Liverpool, London, Birmingham, Leicester and Wales. Survey engagement was high, with a 100% response rate across all questions (20/20). Furthermore, all the healthcare professionals provided contact details for follow-up participation and 18 (90%) expressed an interest in attending the subsequent workshop.

Of the 57 total survey respondents, 37 were individuals living with CLTI or carers of someone affected by the condition. Among this subgroup, 14 participants reported having undergone stent placement while 13 had received bypass surgery. Ten respondents either had not undergone surgical intervention or were uncertain about the procedure they had received. The cohort included 31 female and 6 male participants, with a mean age of 63±8.8 years. Geographical representation was broad, encompassing regions across England, Scotland, Wales, Canada, USA and Australia. Survey engagement was high with a response rate of 92% (34/37) across all questions. Additionally, 34 participants (92%) provided contact information for follow-up and 35 (95%) expressed interest in attending the subsequent workshop.

The R1 questionnaire responses yielded 716 individual codes after 236 duplicates had been removed. These were categorised and sub-categorised into domains. The domains were reviewed and refined by the research team (Table 2) and compared with the R1 responses. This resulted in 35 items presented for prioritisation or rating in the R2 survey, and a list of barriers to participation in rehabilitation which we aim to address when developing the programme content.

Round 2: Questionnaire to assess consensus

A total of 29 participants completed the R2 questionnaire. This cohort included 13 healthcare professionals, each with an average of 10–20 years of clinical experience in managing CLTI, and 16 individuals with lived experience of CLTI (either patients or carers). Among the latter group, the duration of diagnosis ranged from less than six months to over two years. Participants were asked to rate

Table 1 Participant demographics.

Data gathered in Round 1	**n (%)**
Individuals with CLTI/carers	37
Sex	
Male	6 (16%)
Female	31 (84%)
Age (years)	
40–59	8 (22%)
60–79	27 (73%)
80+	2 (5%)
Ethnicity	
White	27 (73%)
Black	1 (3%)
Mixed ethnicity	1 (3%)
Unknown/unclear	8 (22%)
Location	
United Kingdom	20 (54%)
Canada	2 (5%)
America	7 (19%)
Australia	1 (3%)
Unknown/unclear	7 (19%)
Surgery	
Stent	14 (38%)
Bypass	13 (35%)
Neither/unsure	10 (27%)
Healthcare professionals	20
Job role	
Consultant vascular surgeon	4 (20%)
Consultant vascular radiologist	2 (10%)
Professor of vascular surgery	2 (10%)
Speciality registrar in vascular surgery	1 (5%)
Research Fellow	1 (5%)
Lead vascular clinical nurse specialist	1 (5%)
Vascular limb specialist sister	1 (5%)
Vascular assistant practitioner	1 (5%)
Lead vascular scientist	1 (5%)
Advanced clinical practitioner	1 (5%)
Occupational therapist	1 (5%)
Podiatrist	2 (10%)
Physiotherapist	2 (10%)
Location	
United Kingdom	20 (100%)
Data gathered in Round 2	**n (%)**
Individuals with CLTI/carers	16
Diagnosis	
<6 months	2 (18%)
6–12 months	1 (9%)
1–2 years	2 (18%)
>2 years	6 (55%)
Healthcare professionals	13
Experience	
<10 years	4 (31%)
10–20 years	5 (38%)
>20 years	4 (31%)
Data gathered in Round 3	**n (%)**
Individuals with CLTI/carers	3 (33%)
Healthcare professionals	6 (67%)

their agreement on the inclusion of certain elements in the rehabilitation programme or prioritise certain elements.

There was strong consensus (90%) that educational interventions would be beneficial for individuals with CLTI following revascularisation. Consensus was also reached on the inclusion of several key topics within the proposed education programme: the condition and what causes it (97%); other medical conditions and how they are related to CLTI (93%); outcomes and what happens if nothing is done (90%); types of surgery and what it achieves (83%); medication and pain management (86%); and management of risk factors (93%). No topics generated from R1 failed to achieve consensus. Eight additional topics were suggested in the free-text response. Of these, five did not generate any new themes (eg, prevention and walking with pain) and four were deemed out of scope (eg, when to get a second opinion and how to search for physicians).

Regarding delivery methods, person-led presentations were identified as the preferred format (74%), with consensus supporting the involvement of both healthcare professionals (97%) and individuals with lived experience of CLTI (76%) as facilitators. However, consensus was not reached on several aspects of programme design including the optimal duration of presentations (48% agreement for 10–20 minutes), the use of printed leaflets (56%), the inclusion of online video resources (67%) and the recommended length of such videos (52% agreement for 1–10 minutes).

There was strong consensus (90%) that exercise is beneficial for individuals with CLTI following revascularisation. Agreement was achieved on the inclusion of specific activities within the proposed exercise programme – namely, outdoor walking (93%), strength training (79%), balance exercises (83%), cardiovascular/aerobic activity (72%) and breathing or relaxation techniques (72%). Notably, all activities identified during R1 attained consensus for inclusion. Seven additional activities were suggested in the free-text responses. Of these, five had components comparable to current listed activities (eg, Nordic walking and yoga) and two were deemed out of scope due to accessibility and provision (eg, swimming).

Consensus was also reached regarding the recommended frequency of strength and cardiovascular exercises, with 79% and 70% agreement respectively that these should be undertaken 1–3 times per week. However, no clear consensus emerged on the optimal frequency for walking (48% agreement for 4–6 times per week), balance (50% agreement for 1–3 times per week) or breathing/relaxation exercises (59% agreement for every day).

In terms of preferred exercise settings, participants indicated that walking and breathing/relaxation activities are best conducted in the home environment (86% and 85%, respectively) whereas cardiovascular/aerobic sessions were considered more appropriate at a venue (81%). The optimal location for strength and balance exercises remained inconclusive. Additionally, 86% agreed that attending a supervised exercise session would provide social

Table 2 Summary of responses and example quotes from the Round 1 questionnaire

	Summary of responses	Example quotes (Healthcare professional = HP, Individual with CLTI/carer = Pt)
Rehabilitation	Rehabilitation is essential to help individuals improve and return to their previous level of health, physically, mentally and socially. Rehabilitation should encompass an integrated approach that includes physical therapy, psychological support and educational interventions.	"Often it is making someone 'safe enough' to leave hospital rather than a person-centred holistic approach to restoring function" (HP) "I have not had rehab, the healing process is sad, depressing and lonely" (Pt) "The essential pathway to the best possible outcome for the patient" (Pt) "I have completed a cardio rehab programme – it's been invaluable and is the reason I'm alive" (Pt) "Without good rehab other treatment measures' success are at best reduced and at worst a complete waste of time" (HP)
Exercise	Exercise is important for both physical and psychological wellbeing. Benefits include improvements across physical, mental and social domains. Postoperative exercise should be structured, individualised and professionally supervised. Postoperative exercise should include walking, resistance training, sport or recreational activities, mobility and flexibility exercises and cardiovascular training. Suggested exercise frequency varied from once weekly to daily. Suggested durations ranged from 30 minutes to one hour per session. Preferred exercise settings included structured venues, outdoors and at home-based. Barriers included comorbid conditions, negative attitudes, low motivation and limited access.	"Needed as much as food and water" (HP) "Bypasses changed what I can/can't do. I had to figure it (exercise) out and do it on my own" (Pt) "Leg amputation made walking impossible. No one suggested exercise to keep my 1 leg healthy." (Pt) "Prescribed exercise programmes and early follow-up would increase engagement" (HP) "The leisure centre is central to my wellbeing physically and mentally. Exercise and social interaction benefit me and are central to my quality of life" (Pt)
Education	Half of individuals with CLTI or their carers reported a high level of perceived knowledge. The majority of health professionals felt patients possessed limited understanding. Both groups suggested the need for enhanced informational resources. Education should cover the condition itself, exercise recommendations, pain management strategies and approaches to improving overall health outcomes. The benefits of education include behaviour and lifestyle change, enhanced health outcomes, promotion of personal accountability and a sense of empowerment. Suggested formats included written materials, audiovisual content and face-to-face communication.	"If I know, I can do better" (Pt) "Additional info and advice is a prerequisite to taking ownership of my disease and responsibility for rehabilitation implementation, minimising progression of the disease, and living with the status quo" (Pt) "Education empowers patients to take control of their health. When patients understand their condition and steps they can take to manage it they are more likely to adhere to treatment plans and make positive lifestyle changes" (HP) "Delivering information and advice to individuals with CLTI can be most effective when using a combination of methods to cater for different learning preferences and accessibility needs" (HP)

support, and the free-text responses identified additional provision of social support which we aim to address when developing the programme.

While 79% of respondents agreed that walking should be monitored using an activity tracker, consensus was not reached regarding appropriate methods for monitoring or recording strength training (36% agreement for a diary), balance (43% agreement for a diary), aerobic exercises (46% agreement for an activity tracker) and breathing/relaxation (50% agreement for a diary). In summary, of the 35 items presented for evaluation, 23 achieved consensus while 12 items did not meet this criterion.

Round 3: Workshop

A total of nine participants attended the final online workshop. Of these, six were healthcare professionals and three were individuals with CLTI/carers. Twelve items pertaining to exercise frequency, location, monitoring and educational delivery method and timings that had not achieved consensus in R2 were discussed in breakout rooms prior to voting taking place.

Consensus was achieved regarding the recommended structure and delivery of exercise and educational components for individuals with CLTI following revascularisation. It was unanimously agreed that walking should be undertaken 4–6 times per week

(100%) and balance exercises should be performed 1–3 times per week (100%) at home (100%). There was consensus that breathing/relaxation activities should be practised daily (83%) also within the home setting (100%). Whilst there was agreement that strength training should be conducted in a designated venue (100%), there were also discussions during the workshop that strength training should also take place in the home. Furthermore, there was full agreement that all activities should be systematically monitored using a participant-maintained diary (100%).

In relation to educational delivery, consensus was reached that presentations should not exceed 20 minutes in duration (100%). Additionally, it was agreed that educational content should be made available in multiple formats, including printed leaflets (100%) and online videos (100%), with the latter recommended to have a maximum duration of 10 minutes (100%). Additional discussions during the workshop were that physical activity/exercise should be included as a stand-alone educational topic rather than embedded in the risk factors topic. In summary, all 12 items presented in the workshop achieved consensus.

Discussion

The primary aim of this study was to employ a modified Delphi to identify the key components to be included in an individualised rehabilitation programme specifically for individuals with CLTI following revascularisation surgery.

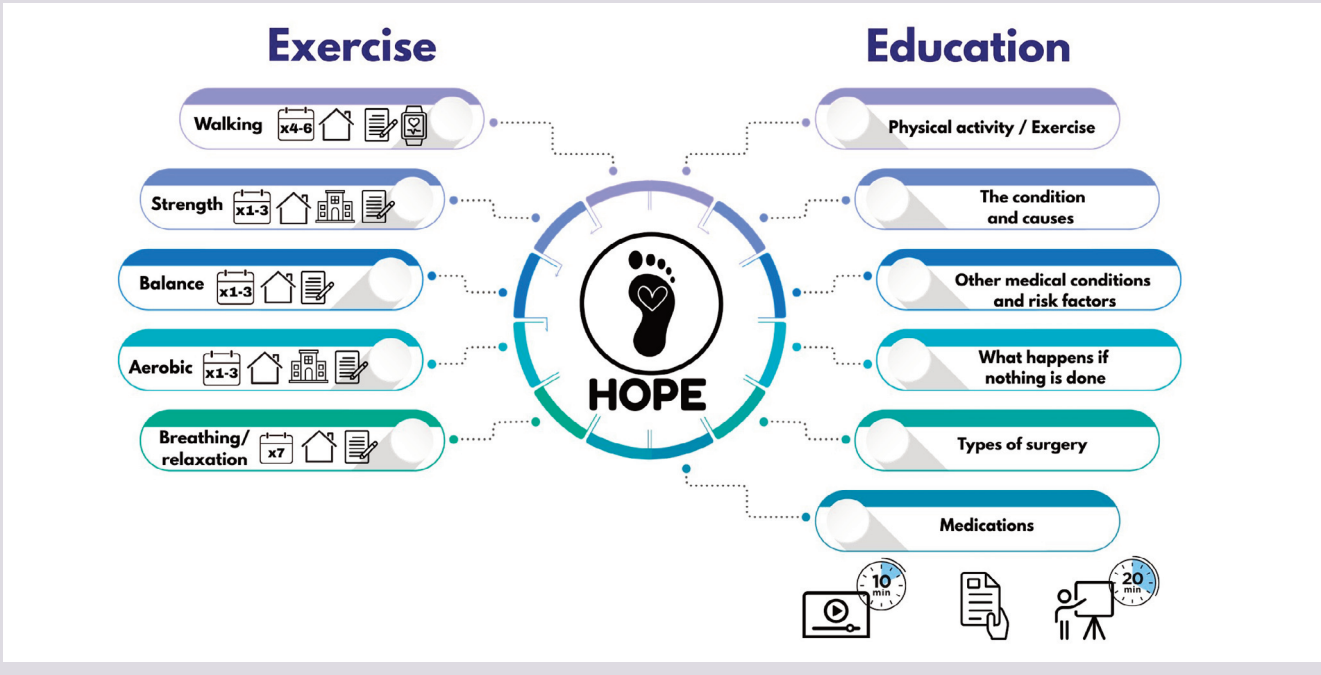
This exercise yielded a final dataset of 35 items which served as the foundation for the design and content of the rehabilitation programme. This dataset delineated the specific activities to be incorporated within the exercise component alongside recommendations regarding their frequency, setting and appropriate methods of monitoring. Additionally, the dataset informed the content to be addressed within the educational component of the programme, including guidance on optimal delivery methods and scheduling (Figure 2).

These findings are consistent with several clinical guidelines for individuals presenting with cardiovascular health conditions.[33–36] All guidance underpins the therapeutic value of education, physical activity and structured exercise in improving functional capacity, symptom burden and quality of life, while also recognising the need for adaptable delivery models to address barriers to access and adherence.

While expert opinion sits at the lowest level of the evidence pyramid,[37] the Delphi method is considered the most widely used consensus group technique for exploring emerging areas of uncertainty,[38] due to the integration of anonymity, iterative rounds, structured feedback and statistical synthesis of group responses.[39] A key strength of this study was the recruitment of a diverse range of international experts including healthcare professionals, individuals living with CLTI and carers. This inclusive approach facilitated the generation of domains that reflect a broad spectrum of perspectives rather than privileging insights from a single subgroup. An additional methodological strength was the geographical diversity of the participant pool, which enhanced the contextual richness and generalisability of the findings.

Across successive rounds, responses from both individuals with CLTI/carers and healthcare professionals demonstrated alignment

Figure 2 HOPE rehabilitation programme.



regarding rehabilitation, education and exercise. A notable divergence, however, emerged in perceptions of patient knowledge. Whilst half of the individuals with CLTI/carers reported knowing 'a lot' about the condition, the majority of healthcare professionals perceived that patients knew 'very little'. Although this aligns with other studies,[40] this discrepancy may simply be due to differing interpretations of what it means to 'know' about CLTI – for example, individuals with CLTI may perceive themselves to be well informed based on lived experience whereas healthcare professionals may assess knowledge based on clinical accuracy or adherence to recommendations. Consistent with other studies,[41,42] however, both groups agreed upon the provision of education within the rehabilitation programme.

Attrition rates are recognised as a limitation of the Delphi technique,[16,43,44] with rates as high as 92% reported in some studies.[45] This study yielded an attrition rate of 49% and 72% across successive rounds, reflecting the challenge of sustaining participant engagement. Although representation from both individuals with CLTI/carers and healthcare professionals was maintained throughout, the final workshop included significantly fewer patients/carers (n=3) than healthcare professionals (n=6), which may have influenced the findings. Although patients are often regarded as the most vulnerable and least empowered members of multidisciplinary teams,[46] active and meaningful participation was observed during the workshop. This engagement was likely facilitated by thorough preparation, facilitator support and the creation of a safe and inclusive environment.[47] Notably, response rates (a key indicator of the validity and reliability of survey-based research)[48] remained robust, consistently exceeding the average reported rate for online surveys (44.1%).[49]

Research to date has primarily focused on supervised exercise therapy for intermittent claudication after revascularisation, and while recent protocols have begun to incorporate patients with CLTI into cardiac rehabilitation,[18] this is, to our knowledge, the first bespoke rehabilitation programme developed exclusively for the post-revascularisation CLTI population. Whilst there is no formal guidance specific to the CLTI population, the European Society of Cardiology and global vascular guidelines certainly advocate exercise following revascularisation.[5] However, this guidance is extremely vague due to the lack of research and data to validate it. This study has taken the initial step forward to address several of the top 10 research priorities as identified by a JLA and Vascular Society of Great Britain and Ireland priority setting partnership, including the number 1 priority: "What can be done to improve outcomes in patients with severe circulation problems to their legs?"

Conclusion

This study has captured the perspectives and opinions of experts, patients and carers to inform the design of a rehabilitation programme suitable for individuals with CLTI following revascularisation surgery.

KEY MESSAGES

- Despite successful revascularisation, outcomes for those with CLTI remain poor.
- This study harnessed the insights of healthcare professionals, individuals with CLTI and carers to develop a rehabilitation programme for those with CLTI following revascularisation.
- This is an initial step to address key research priorities in PAD as identified in a JLA priority setting partnership.
- The next step is a multicentre feasibility trial.

The key components of the programme include a range of physical activities (aerobic, strength training and balance) to be carried out at home and in a supervised venue, all monitored via diary and an activity monitor. A range of educational topics were identified, all to be delivered via presentations and supported with information leaflets and online videos.

While the results align with current guidelines provided for those with similar clinical conditions, this is the first individualised rehabilitation programme specific to this population. This study has taken initial steps to address key research priorities and the next step is to conduct a multicentre feasibility trial in both community and NHS settings.

Conflict of Interest: None declared.

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Ethics: This study was reviewed by the Science and Engineering Research Ethics and Governance Committee at Manchester Metropolitan University and was given a favourable ethical opinion on 2 January 2024. EthOS Reference Number: 55518. Participants gave consent to take part in this study.

Data sharing: All data relevant to the study are included in the article or uploaded as supplementary information. Other data if required are available on reasonable request.

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ORIGINAL RESEARCH

A national UK-wide survey of tranexamic acid use in vascular surgery

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Plain English Summary

Why we undertook the work: During vascular surgery (surgery on major blood vessels of the body), some patients can lose a large amount of blood. Tranexamic acid (sometimes called TXA) is a medicine that reduces breakdown of clots and can reduce bleeding. It is widely used in other situations such as trauma, childbirth and heart surgery where it has been shown to save lives and to reduce serious bleeding and the need for blood transfusions. However, TXA is not commonly used in vascular surgery. Vascular operations involve arteries, veins and sometimes artificial or vein grafts, and doctors worry that TXA might cause dangerous blood clots. These clots could block blood flow to important organs and limbs. At present there is not enough strong evidence to clearly show whether TXA is safe or helpful for patients having vascular surgery. We wanted to find out how TXA is currently used across the UK in vascular surgery, what doctors think about its risks and benefits, and whether there is support for more research.

What we did: We carried out a UK-wide survey of vascular surgeons and anaesthetists. Doctors were asked how often they use TXA in different planned (elective) and emergency vascular operations. They were also asked about their concerns regarding bleeding and blood clots, and whether they believed further research was needed. The survey included doctors from most vascular units across the UK, providing a national overview of current practice and opinions.

What we found: We found that TXA is rarely used in vascular surgery. Most doctors only give TXA when there is severe bleeding, rather than as a standard treatment. Doctors were especially concerned about blood clots during procedures where keeping arteries or grafts open is critical. TXA was therefore used very infrequently in operations such as carotid artery surgery and leg bypass surgery, where even a small clot could have serious consequences. In emergency situations such as surgery for a ruptured abdominal aortic aneurysm, TXA was used more often, particularly when there was major blood loss. Even so, practice varied widely between hospitals and between doctors. Most doctors felt that the current evidence about TXA use in vascular surgery is not enough. Many said they would support and take part in a future research study provided patient safety – especially the risk of blood clots – was carefully assessed.

What this means: TXA use in vascular surgery varies widely across the UK and is usually limited to situations involving heavy bleeding. Doctors remain cautious because of concerns about blood clots affecting vital blood vessels or grafts. However, TXA may have important benefits for some patients, particularly in operations where the risk of blood loss and the need for blood transfusion is high. In these situations, TXA may reduce bleeding and transfusion requirements. There is strong support for further research, including a carefully designed clinical trial, to determine whether TXA can be used safely and effectively in vascular patients. Such research should focus not only on bleeding but also on important safety outcomes such as stroke, graft blockage and the need for further surgery.

Abstract

Background: Tranexamic acid (TXA) is widely used to reduce perioperative bleeding in several surgical specialties; however, its role in vascular surgery remains uncertain. Concerns regarding arterial, venous and graft thrombosis, together with limited and low-certainty evidence of efficacy, have contributed to variation in practice across the UK. According to the 2025 National Vascular Registry there were nearly 20,000 major vascular operations carried out across the four nations. The 2023 NHS Blood and Transplant audit found TXA uptake in vascular surgery to be low (26.5%) when compared with other specialties such as cardiac, orthopaedic and trauma surgery, which each had TXA use over 80%. We set out to understand clinician perspectives to inform the design and possible need for a future trial.

Methods: We conducted a national cross-sectional survey of vascular anaesthetists and surgeons across the UK between December 2024 and June 2025. The questionnaire assessed TXA use in elective and emergency vascular procedures, perceptions of bleeding and thrombotic risk, and views on the adequacy of existing evidence and the feasibility of a future randomised controlled trial (RCT). Quantitative data were analysed descriptively and free-text responses were analysed thematically.

Results: A total of 142 responses were received from 49/65 (74.6%) UK vascular units. This included 85 anaesthetists and 57 surgeons, the majority of whom were consultant grade. Routine TXA use was uncommon across elective procedures, while selective use increased in the context of major haemorrhage, particularly during emergency surgery. Respondents perceived carotid surgery and lower limb revascularisation as carrying the highest risk of arterial or graft thrombosis, whereas trauma and major lower limb amputation were viewed as highest risk for venous thromboembolism; these perceptions were reflected in reported practice. Support for further research was high: 67/85 anaesthetists (79%) and 36/57 surgeons (63%) believed that an RCT evaluating TXA in vascular surgery is needed, with most favouring inclusion of both elective and emergency procedures. Willingness to recruit patients was reported by 77/85 anaesthetists (90%) and 42/57 surgeons (74%), although respondents noted that recruitment would depend on procedure type and multidisciplinary agreement. Safety considerations dominated views on trial design. Graft or arterial thrombosis up to 90 days was prioritised by 83/85 anaesthetists (98%) and 53/57 surgeons (93%), followed by return to theatre for bleeding or thrombosis and transfusion requirements. Most respondents (74/85 anaesthetists (87%) and 45/57 surgeons (79%)) indicated they would change practice if a well-designed trial demonstrated both safety and efficacy.

Conclusion: TXA use in vascular surgery is variable and context dependent. There is substantial clinical equipoise and strong support for a randomised trial, providing the study design reflects procedural heterogeneity and prioritises safety-related outcomes.

Key words: tranexamic acid, vascular surgery, thromboembolism, blood transfusion, bleeding

Introduction

Tranexamic acid (TXA) is a synthetic lysine analogue that inhibits fibrinolysis and reduces surgical bleeding by stabilising clot formation.[1] Large randomised trials have demonstrated its efficacy in a range of clinical settings including trauma, postpartum haemorrhage and cardiac surgery, where TXA has been associated with reductions in mortality, critical bleeding and transfusion requirements.[2–5] National and international guidelines, including NICE guidance on blood transfusion, recommend TXA for all surgical patients with anticipated blood loss exceeding 500 mL, irrespective of surgical specialty. However, these recommendations are not specific to vascular surgery and do not address some of the specialty-specific concerns.[6,7]

In vascular surgery, TXA use has been less consistent,[8] largely related to concerns around vessel and/or graft thrombosis.[9,10] A recent systematic review and meta-analysis of randomised trials of TXA in vascular surgery found no evidence of increased arterial or venous thromboembolic events, and no clear reduction in critical bleeding or transfusion requirements.[11] However, the certainty of the evidence was low due to small sample sizes, few events and heterogeneity in study design, patient selection, dosing regimens and outcome reporting. As a result, whether TXA is beneficial, safe or indicated in vascular surgery remains uncertain.

The 2025 National Vascular Registry (NVR) report showed that there were 6,982 lower limb revascularisations, around 2,500 elective abdominal aneurysm repairs, nearly 6,000 carotid endarterectomies and over 3,800 major lower limb amputations carried out. National audit data in the UK consistently show a low rate of TXA administration in patients undergoing vascular surgery (26.5%) and who are potentially eligible to receive TXA compared with other specialities such as orthopaedics (92.7%).[12] Surveys from other health systems have indicated wide variation in TXA use in vascular surgery and differences in practice and opinions between anaesthetists and surgeons.[13] Whether similar patterns exist in the UK is unknown.

The feasibility of conducting a vascular-specific randomised controlled trial (RCT) of TXA in the UK, including willingness to recruit, appropriate endpoints and concerns regarding safety, has not been systematically evaluated. We therefore conducted a national survey to: (1) assess vascular surgeons' and anaesthetists' perceived risk of thrombosis and bleeding and understanding of the available evidence; (2) ascertain current patterns of TXA administration in vascular surgery; and (3) obtain views to inform the design of a future TXA RCT in vascular surgery.

Methods

This report has been prepared according to the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guideline[14] (see Appendix 1 online at www.jvsgbi.com).

A national cross-sectional survey was conducted between December 2024 and June 2025. A questionnaire was piloted internally and the survey wording was shared with and approved by the research committees of the Vascular Anaesthesia Society of Great Britain and Ireland (VASGBI) and Vascular Societies of Great Britain and Ireland (VSGBI) prior to circulation. The survey was hosted on the VASGBI online survey platform. Members of VSGBI and VASGBI were invited to participate through direct email communication and professional mailing lists; no financial incentives were provided. Several answers per unit were allowed. An example template of the survey is provided in Appendix 2 online at www.jvsgbi.com.

The survey was developed iteratively by a multidisciplinary team comprising vascular anaesthetists and surgeons. Questions evaluated current patterns of TXA use in elective and emergency vascular procedures, risk–benefit perceptions, beliefs regarding the need for further research and willingness to enrol patients in a future RCT. Both closed-response questions and free-text fields were included. Free-text fields were optional, but all other questions were mandatory resulting in no missing responses or incomplete forms. Closed-response questions used categorical frequency scales (eg, 'routinely', 'used only in major haemorrhage', 'rarely', 'never'), and respondents were asked to select procedure-specific responses for elective endovascular abdominal aneurysm repair (EVAR), open abdominal aortic aneurysm (AAA) repair, lower limb revascularisation, major lower limb amputation, carotid endarterectomy and ruptured AAA (open and endovascular). Items relating to potential trial recruitment, outcome prioritisation and TXA dosing were also included.

Data were analysed descriptively. Categorical responses were summarised as frequencies and proportions. Free-text responses were grouped into broad thematic categories which emerged during analysis using a descriptive non-formal thematic approach. The map was created using Datawrapper, and Graph Pad Prism 10 was used to create all other figures.

Results

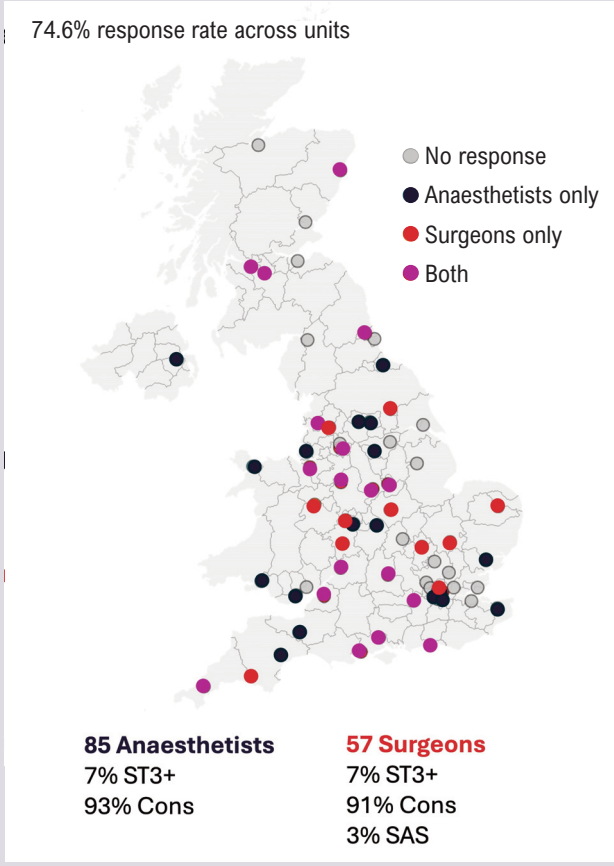
Respondents

A total of 142 survey responses were received from 49/65 (74.6%) UK vascular units. Of these, 85 respondents were anaesthetists and 57 were surgeons. The majority of respondents (~90%) were consultant grade, with a small proportion in training (7% at ST3+). Responses were received from institutions across the UK, indicating broad national coverage (Figure 1).

Perceived risk of thrombosis and bleeding

Respondents were asked to rank the perceived risk of venous thromboembolism (VTE) and arterial or graft thrombosis across seven common vascular procedures. Trauma and major lower limb amputation were identified as having the highest VTE risk (78% and 73%, respectively) by both surgeons and anaesthetists. In contrast, lower limb revascularisation was viewed as the procedure with the highest risk of arterial or graft thrombosis, selected by 44/57 (77%) surgeons and 72/85 (85%) anaesthetists, followed by carotid endarterectomy and stenting (selected by 37/57 (64.9%) surgeons and 42/85 (49.4%) anaesthetists). This perception was echoed in free-text responses, with respondents frequently expressing concern about graft occlusion. For example, one surgeon noted "clot is your enemy" and questioned the rationale for TXA use when anticipated blood loss is minimal but thrombotic risk is substantial.

Figure 1 Distribution of responses from vascular anaesthetists and surgeons across vascular units in the UK.

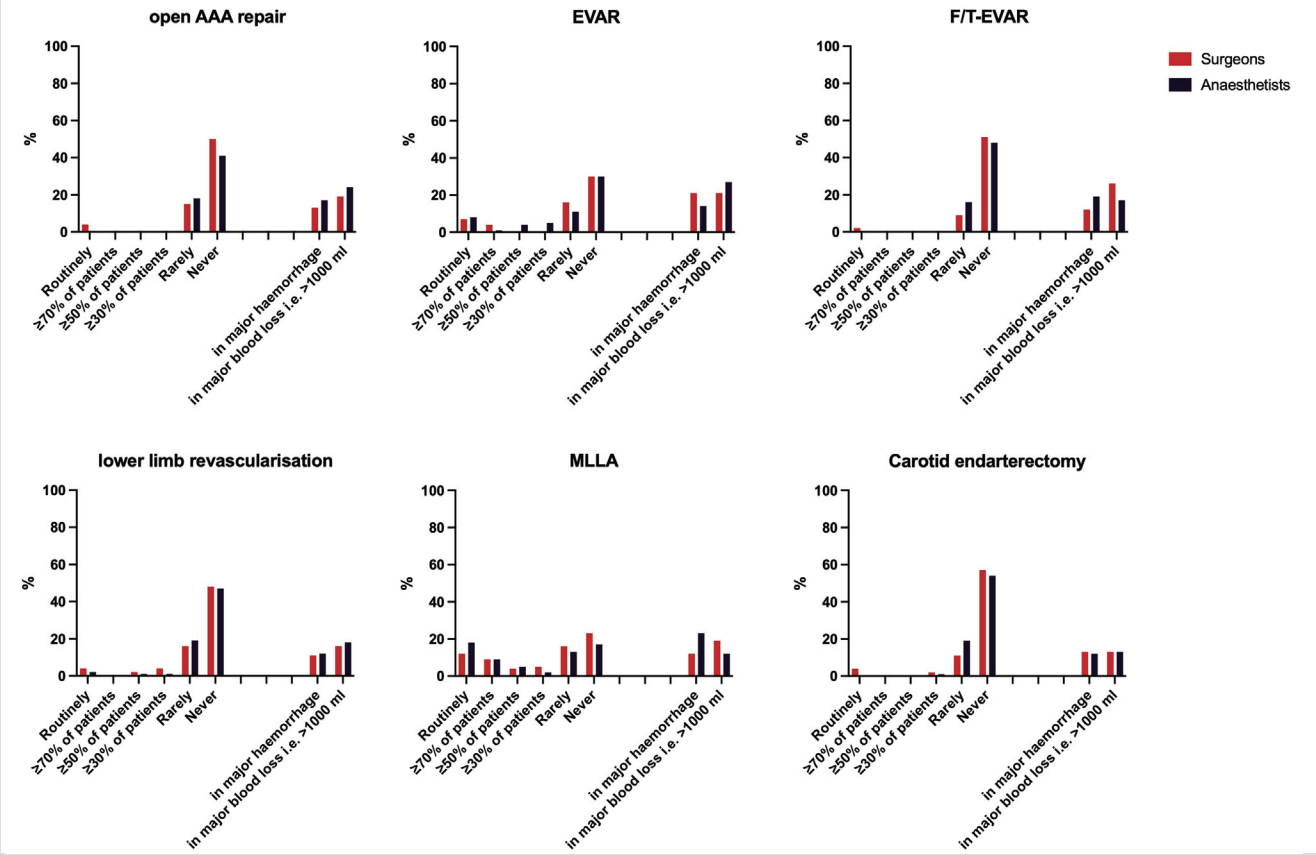


Current practice in elective surgery

Across all elective procedures, TXA use was infrequent. For elective EVAR, open AAA repair, lower limb revascularisation and major lower limb amputation, most respondents indicated that TXA was 'rarely' or 'never' used. Fewer than 10% of respondents reported routine administration in any elective procedure.

There was, however, a consistent increase in administration in the context of major haemorrhage. For elective AAA surgery, 12/57

Figure 2 Patterns of tranexamic acid (TXA) use in select elective vascular surgeries. Possible survey responses ranged from 'routinely' to 'never'. AAA, abdominal aortic aneurysm; EVAR, endovascular aneurysm repair; MLLA, major lower limb amputation.



(21%) surgeons and 22/85 (27%) anaesthetists reported giving TXA when blood loss exceeded 1000 mL. Practice for lower limb revascularisation and amputation followed similar patterns, although the absolute proportion of routine or selective use remained low (Figure 2).

Current practice in emergency surgery

Greater variability was observed in emergency practice. For ruptured AAA, 18% of anaesthetists (15/85) reported routine use of TXA during open repair compared with 12% of surgeons (7/57). Routine use was less common for ruptured EVAR. As with elective procedures, the use of TXA increased during major haemorrhage, with several respondents indicating administration when blood loss was >1000 mL, regardless of procedure type (open repair vs EVAR).

For emergency lower limb revascularisation and amputation as well as emergency carotid surgery, TXA was rarely used routinely, although a minority of clinicians administered TXA selectively in cases of major bleeding (Figure 3).

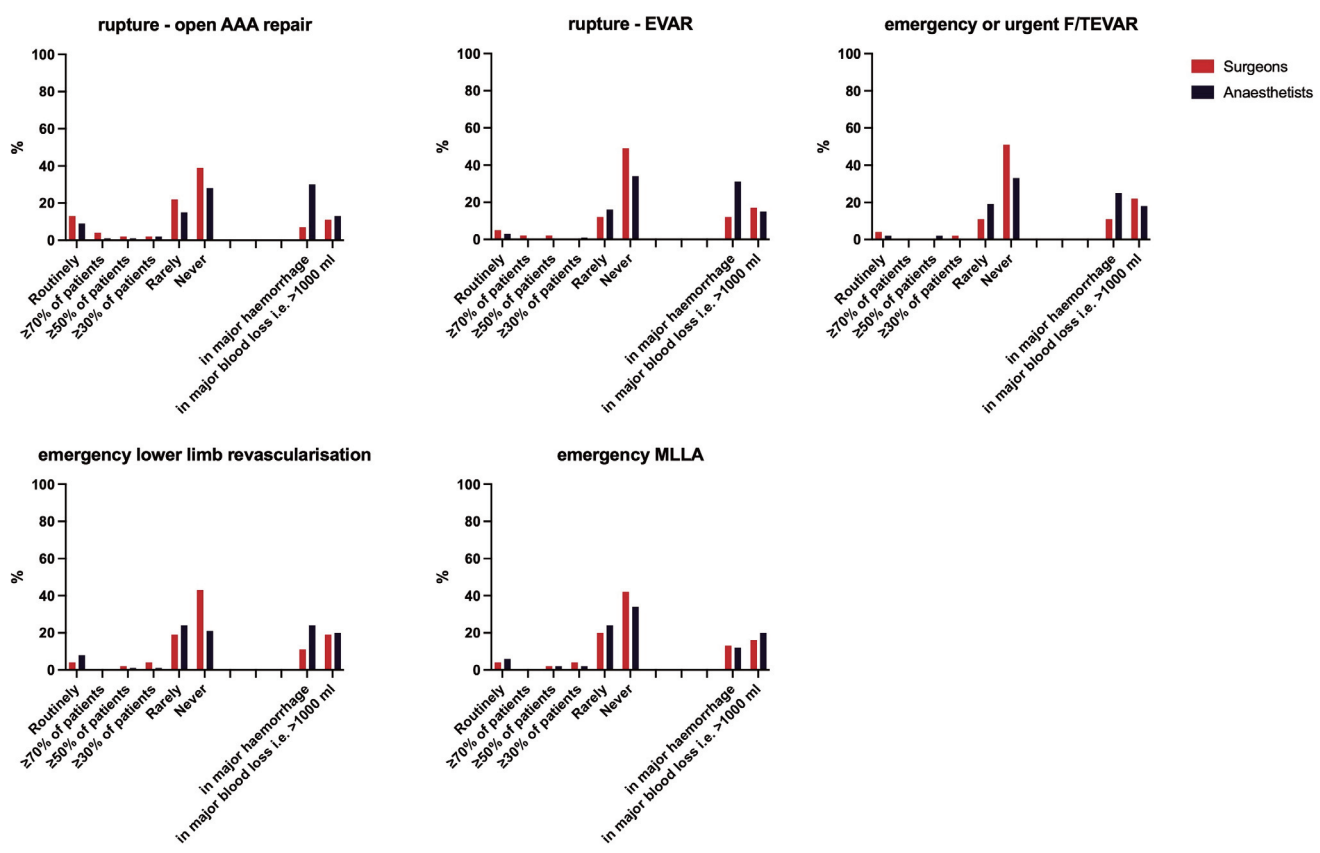
Directions for future research

The majority of respondents expressed support for further research evaluating the role of TXA in vascular surgery. Overall, 67/85 (79%) anaesthetists and 36/57 (63%) surgeons believed that an RCT was needed, with most favouring a study including both elective and emergency procedures. There was broad consensus that the current evidence is insufficient to guide practice in this specialty, particularly given the perceived heterogeneity of risk across vascular procedures (Figure 4).

In addition to recognising the need for further evidence, most clinicians indicated that they would be willing to participate in an RCT (77/85 (90%) anaesthetists and 42/57 (74%) surgeons). The most common position was that participants would consider randomising some or all potential patients, with the extent of willingness varying according to procedure type. Several respondents noted that successful enrolment would depend on multidisciplinary agreement between surgeons and anaesthetists (Figure 4).

Although only a minority of respondents reported that they would not enter any patients into a trial (four anaesthetists and nine surgeons), those with reservations raised consistent concerns. The most cited concern was the perceived risk of arterial or graft thrombosis (two anaesthetists and six surgeons), particularly in operations in which patency is essential to limb perfusion or stroke prevention (Figure 4).

Figure 3 Patterns of tranexamic acid (TXA) use in select emergency vascular surgeries. Possible survey responses ranged from 'routinely' to 'never'. AAA, abdominal aortic aneurysm; EVAR, endovascular aneurysm repair; MLLA, major lower limb amputation.



Respondents were also asked to identify outcomes that they considered important for any future study. The most selected outcomes were graft or arterial thrombosis up to 90 days (83/85 (98%) anaesthetists and 53/57 (93%) surgeons), return to theatre for bleeding or thrombosis (75/85 (88%) anaesthetists and 49/57 (86%) surgeons), and transfusion requirements (64/85 (75%) anaesthetists and 38/57 (67%) surgeons. Perioperative VTE was also frequently selected. Other outcomes including acute kidney injury, length of stay, days alive and at home, and cost-effectiveness were chosen less frequently. These results indicate that safety-related endpoints were prioritised more often than measures of clinical efficacy (Figure 4).

Lastly, respondents were asked whether they would change their practice if a study showed that TXA was both safe and effective; 74/85 (87%) anaesthetists and 45/57 (79%) surgeons indicated that they would alter practice in accordance with results from a well-designed and effectively conducted trial.

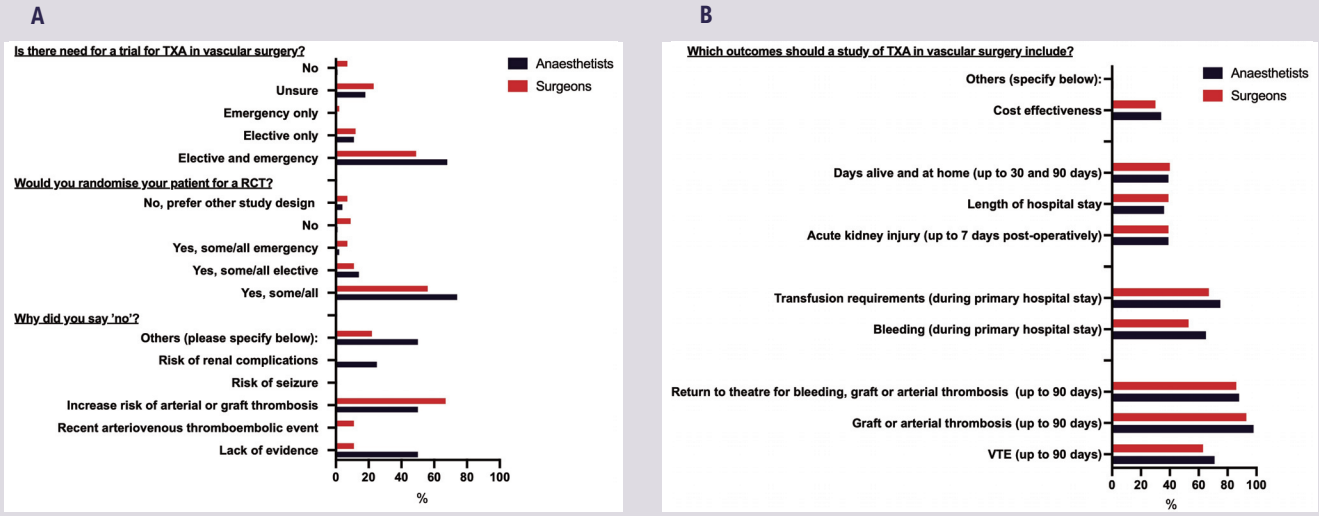
Preferred dosage of TXA

Most respondents indicated that they would use a 2 g dose, consistent with current national recommendations (53/85 (62%) anaesthetists and 35/57 (61%) surgeons).15 A smaller proportion favoured a 1 g dose (22/85 (26%) anaesthetists and 11/57 (19%) surgeons) and very few stated that they would not use TXA at all. Free-text comments highlighted uncertainty regarding the optimal dose, timing relative to heparinisation and the need for evidence specific to vascular patients.

Qualitative analysis

The optional free-text responses provided some important and interesting additional insights complementing the survey responses and reflected both recognition of uncertainty and support for further high-quality evidence. The two emerging themes of the free-text comments were identified as: (1) need for further evidence with demonstration of superiority; and (2) importance of multidisciplinary agreement and collaboration. One anaesthetist commented: "I am so glad you are asking this question", while another emphasised the central concern underpinning current practice, stating: "I need strong evidence that it is harmless and makes the outcome significantly better before I start using it in vascular cases". Similarly, surgeons expressed reservations about routine use in the absence of robust data, with one noting: "I just don't feel there is enough evidence to justify its use in this patient cohort". There were expressed safety concerns, with one surgeon noting: "The paper

Figure 4 Survey responses assessing the need for a future randomised controlled trial (RCT) studying tranexamic acid (TXA) use in vascular surgery. (A) Is there a need for a trial? Would you enrol your patients in an RCT? If no, what are your concerns? (B) What outcomes should an RCT look at?



you quote specifically excluded vascular patients. I just don't feel there is enough evidence to justify its use in this patient cohort. I can't remember a death from bleeding, but I remember plenty related to ischaemic events: stroke, ischaemic bowel, MI, etc". Two participants described prior adverse experiences or institutional anecdotes, including cases of limb loss following what they believed to be inappropriate TXA administration in the context of ruptured AAA. Other respondents questioned whether an RCT was feasible in a population with multiple confounding variables including comorbidities, antiplatelet or anticoagulant use, variations in surgical technique and the timing of TXA administration relative to intraoperative heparinisation. One respondent reflected this concern, stating: "There are so many variables that contribute to bleeding, which include the continued use of antiplatelets (mono and dual antiplatelet therapy), timing of heparinisation and, most importantly in my view, the surgical technique". A small number (one anaesthetist and two surgeons) suggested that the existing evidence base was sufficient or that alternative designs, such as observational data or pooled registry analyses, might better address remaining uncertainties.

Discussion

In this national survey of vascular surgeons and anaesthetists we found that TXA use in vascular surgery was infrequent, with routine administration uncommon across both elective and emergency procedures. When used, TXA was most frequently given in the context of major haemorrhage and rarely in procedures associated with minimal blood loss. Despite national recommendations supporting TXA for surgical bleeding, respondents reported considerable variation in practice, reflecting specialty-specific concerns and differences in perceived risk. Additionally, while large contemporary trials such as POISE-3 included patients undergoing non-cardiac surgery including vascular procedures, procedural subtypes were not reported in detail and distinctions between elective and emergency vascular operations were not specified. Given the heterogeneity in bleeding and thrombotic risk across vascular operations, extrapolation to specific vascular contexts remains challenging, which may partly explain the ongoing variation identified in our survey.

A key finding was the contrast between perceived bleeding and thrombosis risks across procedures. Respondents consistently identified carotid surgery and lower limb revascularisation as operations with a high risk of graft or arterial thrombosis, whereas trauma and major lower limb amputation were viewed as highest risk for VTE. These differences are likely to influence decision-making; procedures with limited expected blood loss and high thrombosis risk were associated with low levels of TXA administration whereas TXA use was more common in operations with major haemorrhage, particularly ruptured AAA repair. This procedural variation illustrates that clinicians appear to consider TXA within the context of specific operative risks rather than applying uniform practice. However, volume of anticipated blood loss alone may not fully capture bleeding-related risk. In anatomically constrained procedures such as carotid surgery, even limited haemorrhage may have clinically relevant consequences, suggesting that the relevance of TXA may depend not only on the volume of bleeding but also on the potential impact of bleeding in specific operative contexts. Although there appeared to be differences in use rate between anaesthetists and surgeons (with higher reported use rate by anaesthetists), this might reflect responses from different units where different practice might have been agreed; this should not be interpreted as different practice between specialties.

Most respondents supported further research, with the majority

of anaesthetists and surgeons indicating that an RCT was needed. These findings suggest that equipoise exists, yet practical considerations (eg, dose and timing of TXA, nature of procedure) may be essential for recruitment.

Respondents prioritised safety-related outcomes specific to vascular surgery for any future RCT. Graft or arterial thrombosis up to 90 days, return to theatre for bleeding or thrombosis, and transfusion requirements were the most frequently selected endpoints. Measures of bleeding alone were selected less often, indicating that clinicians were more concerned with avoiding thrombotic complications than reducing modest blood loss. These preferences have implications for trial design; outcomes should focus on both bleeding and thrombosis, and follow-up should extend beyond the immediate perioperative period to capture clinically relevant events such as graft failure and stroke.

This survey highlights the need for procedure-specific and context-specific evidence. Vascular surgery encompasses a heterogeneous group of operations that vary widely in expected blood loss, duration and risk of thrombosis. Elective procedures such as carotid endarterectomy, which typically involve minimal bleeding and are highly dependent on preserving arterial patency, may not warrant prophylactic TXA administration whereas open aortic surgery or ruptured aneurysm repair may represent circumstances in which TXA could be beneficial. Nonetheless, these scenarios also represent the settings in which the balance between bleeding control and arterial thrombosis is most precarious, as rupture complicated by acute limb ischemia is associated with high morbidity and mortality. Similarly, the distinction between elective and emergency surgery is relevant; TXA may be used more readily in emergencies with established or anticipated haemorrhage whereas its role in elective settings is less clear. Future studies should account for these differences rather than treating 'vascular surgery' as a uniform category.

It is noteworthy that national NHS Blood and Transplant (NHSBT) audit data report TXA administration in 26.5% of eligible vascular surgical cases, a figure higher than the rates of routine use reported in our survey (generally <10% in elective settings and up to 18% in emergency open repair). While these findings do not directly align, several factors may explain the disparity. First, our survey captured self-reported routine practice, which may further reflect clinicians' cautious approach to prophylactic use. Second, the NHSBT data do not specify procedural context (eg, elective versus emergency surgery or specific operation types). In our study TXA use was higher in emergency ruptured aneurysm repair, suggesting that aggregate audit figures may reflect case mix rather than uniform practice across procedures.

Limitations

This study has certain limitations. Firstly, it relied on self-reported practice, which may not reflect actual use in theatre, and the number of respondents from some units was small. We disseminated our survey widely to vascular surgeons and anaesthetists, but acknowledge that the response rate with 57 surgeons and 85 anaesthetists is low in the context of over 500 consultant vascular surgeons and nearly 500 consultant anaesthetists who are VASGBI members. However, we feel that receiving a response from almost three-quarters of all vascular units provides a good representation of current practice across the UK. Additionally, survey response bias is possible, although the high unit response rate and predominance of consultant grade participants suggest that the findings are reflective of current national practice. Moreover, we did not collect or analyse linked responses between surgeons and anaesthetists within the same unit (or perform unit level clustering analysis) and responses were anonymised at the individual level. As such, we were unable to determine whether reported differences reflected true intra-team variation or differences between institutions. Nevertheless, the survey provides the first national overview of TXA use in UK vascular surgery and identifies key priorities for research. The findings demonstrate support for an RCT, highlight the importance of multidisciplinary collaboration, and underscore the need to evaluate outcomes that reflect both bleeding and thrombosis risk.

KEY MESSAGES

- Variation in the use of TXA across elective and emergency vascular surgery remains despite national recommendations
- There is equipoise for a trial of TXA use in vascular surgery in the surveyed community
- Future research should focus on multidisciplinary involvement and include meaningful endpoints

Conclusion

TXA use in vascular surgery is inconsistent, and most clinicians reserve it for situations of major haemorrhage rather than routine administration. Respondents expressed broad support for further research, with willingness to recruit patients to a randomised trial providing the study design addresses safety concerns and reflects procedural variation. Outcomes relating to graft or arterial thrombosis, return to theatre and transfusion were prioritised, indicating that safety parameters are central to clinical decision-making.

These findings indicate that equipoise exists for a randomised trial of TXA in vascular surgery. Future research should focus on procedure-specific and elective versus emergency contexts, with attention to multidisciplinary agreement and clinically meaningful endpoints. Results from such studies are likely to inform best practice and guide the appropriate use of TXA in this diverse surgical population.

Conflict of Interest: AS is an editor of Anaesthesia and has served on the NICE Blood Transfusion (Tranexamic acid update) Committee and on the Association of Anaesthetists' Working Party for developing guidelines on the use of blood components and their alternatives. KDB is a member of the Associate Editorial Board at BJS/BJS Open. The remaining authors have no conflicts of interests to declare.

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Author contributions: KA: Data extraction and analysis; preparation of figures and composition of the initial and final manuscript. AS: Study design; content expertise and co-supervision; data analysis; composition of the final manuscript. JF: Study design; data analysis; content expertise; composition of the final manuscript. KB: Study design; data analysis; preparation of figures; composition of the final manuscript; overall supervision of this work.

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ORIGINAL RESEARCH

Can pre-existing CT or MRI scans be used to improve efficiency and ascertainment in the NHS Abdominal Aortic Aneurysm Screening Programme (NAAASP)?

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Plain English Summary

Why we undertook the work: The NHS Abdominal Aortic Aneurysm Screening Programme (NAAASP) invites men in the 12-month period in which they turn 65 for a one-time ultrasound scan of the abdominal aorta to check for the presence of an abdominal aortic aneurysm (AAA). The abdominal aorta is the main blood vessel that runs from the heart down through the chest and abdomen. An AAA is a bulge or swelling in the aorta. Patients with AAA are often asymptomatic, but once the aneurysm ruptures, it is almost always fatal. NAAASP aims to detect AAAs in the early stage while they are smaller and less prone to rupture. There has been a reduction in the percentage of aneurysmal abdominal aortas detected by NAAASP over the last few years, reducing the cost-efficiency of the screening programme. Some men invited to the screening will have already had a previous 3D scan (eg, CT or MRI) for other reasons, which is sufficient to exclude an AAA for screening purposes.

What we did: We quantified the percentage of men invited to the Cambridgeshire NAAASP who had a previous CT or MRI scan (3D scans) with a suitable view of the abdominal aorta within each of the last six years prior to their NAAASP screening date.

What we found: Within our local screening programme we found that 7% of men have had a recent 3D scan with a view of the abdominal aorta within three years prior to their screening. This would reasonably be considered safe and sufficient to exclude an AAA for screening purposes. Additionally, some men who missed their appointment have also had a previous appropriate 3D scan within three years of their screening.

What this means: There is potential to increase the cost-effectiveness of the NAAASP by not inviting men with a recent 3D scan showing an aneurysm-free abdominal aorta for further imaging. In addition, identifying previous suitable 3D scans for men who do not attend their appointment confirms their aneurysm status without requiring a visit. While this does not change the screening uptake, it effectively improves the overall coverage of the eligible population.

Abstract

Background: The NHS Abdominal Aortic Aneurysm Screening Programme (NAAASP) invites men in the 12-month period in which they turn 65 for a one-time ultrasound scan of the abdominal aorta to assess for the presence of an abdominal aortic aneurysm (AAA). Detecting an asymptomatic AAA affords the opportunity to electively repair it before a potentially fatal rupture. However, there has been a reduction in the percentage of aneurysms detected by NAAASP over the last few years, reducing the cost-efficiency of the screening programme. It is hypothesised that a proportion of men may have pre-existing 3D imaging (eg, CT or MRI) of the abdomen undertaken for an alternative reason, which could be used to exclude an AAA. This may negate the need for a further dedicated screening scan with potential cost savings and improvement in ascertainment. This study aims to quantify the proportion of men in whom there exists satisfactory previous 3D imaging by examining a screened population invited to a single NAAASP centre. Potential cost savings and any impact on ascertainment will be estimated.

Methods: Records for 1000 consecutive patients invited to the NAAASP in Cambridgeshire between late 2022 and early 2023 were evaluated. After exclusions, imaging records for 694 were searched for previous CT or MRI scans within the last six years with an adequate view of the abdominal aorta. The first most recent suitable scan undertaken before the patient's screening date was used, and any prior scans disregarded. Three years was considered a

'safe' retrospective period to screen out a normal aorta and be confident clinically of not missing a new aneurysm that had developed in the intervening period. However, we collected data on double this time span for the purposes of this project.

Results: 7% of the population had a pre-existing 3D scan sufficient to exclude an AAA undertaken within three years prior to their screening date and 12% within six years. This can be further broken down by the cumulative time interval as follows: within one year (n=19, 2.74%), within two years (n=37, 5.33%), within three years (n=48, 6.92%), within four years (n=60, 8.65%), within five years (n=68, 9.80%), within six years (n=82, 11.82%). By extrapolating our findings to the whole NAAASP cohort in Cambridgeshire for the year 2022–2023 (n=6703), we estimated the potential cost savings of ultrasound appointments saved for the NAAASP in Cambridgeshire if men with previous scans within three years were not invited for additional screening to be £17,046, equivalent to a reduction of approximately 464 screening appointments. Assuming a similar national distribution, we estimate potential national cost savings to be £800,819 in saved ultrasound slots if scans within three years were looked at.

Conclusion: 7% of men invited to the NAAASP have had previous 3D imaging sufficient to exclude an AAA within the last three years without additional imaging. These pre-existing data could be used to improve the cost-effectiveness of the screening programme and increase ascertainment.

Key words: abdominal aortic aneurysm, vascular surgery, NHS Abdominal Aortic Aneurysm Screening Programme (NAAASP), cost-effective

Introduction

Abdominal aortic aneurysms (AAAs) are abnormal dilatations of the aorta below the diaphragm and before its bifurcation into the two common iliac arteries. The majority of AAAs are asymptomatic but, with time, the AAA grows and with it the chance of rupture, at which point it is often fatal.[1] Early detection and monitoring improves patient outcomes by allowing an intervention to occur before the aneurysm reaches the point of rupture.[2]

The National Health Service (NHS) Abdominal Aortic Aneurysm Screening Programme (NAAASP) is a nationwide screening programme in the UK that was fully implemented in 2013 with the aim of reducing death from AAA. The NAAASP invites men in the 12-month period in which they turn 65 for a one-time ultrasound scan of the abdominal aorta. Following screening, men with aneurysms measuring 3 cm or more are invited for follow-up surveillance scans, with aneurysms measuring 5.5 cm or more meeting the threshold for referral to vascular surgery.[3]

National screening programmes for AAA such as NAAASP have been shown to be cost-effective.[4,5] But since the screening programme began, there has been a reduction in the prevalence of aneurysms detected. Reasons for this have been hypothesised, including an increased incidental detection rate (when a patient is scanned for a reason other than a suspected AAA) or the lowering of smoking rates, which is the biggest known modifiable risk factor for AAA development.[5] Within the NAAASP there has been a reduction in the percentage of positive scans since the full implementation of the programme in 2013–2019 (from around 1.2% in 2013/14 to less than 0.8% in 2018/19).[6] Furthermore, in the year 2022–2023 the aneurysm detection rate in the NAAASP fell to around 0.76%.[7] The lower the detection rate or prevalence of AAA at screening, the less cost-effective the screening programme becomes.[5]

A possible way to increase the cost efficiency of the NAAASP would be to use pre-existing imaging (CT or MRI), where it exists, to screen out an AAA, negating the need for an additional dedicated NAAASP ultrasound scan. Such 3D imaging would need to be of adequate quality to fully visualise the abdominal aorta and contemporary enough to allay the concern that an AAA may have developed in the intervening period. In addition to potentially reducing the number of unnecessary screening scans, there is potential to mitigate the inefficiency of 'Did Not Attend' appointments. A percentage of men fail to attend their screening, wasting NHS time and money. Where prior 3D imaging exists, the health status of these men can still be determined without a visit. This effectively increases the overall ascertainment of the eligible population, ensuring safety even for those who do not engage with the traditional screening pathway. This is of importance as the number of men in the NAAASP is increasing but the prevalence of AAA detected at screening is not.[7]

Both CT and MRI have been shown to be adequate imaging modalities for the detection of AAA.[8] Previously, the suitability of using previous CT scans done within a few years of ultrasound screening to retrospectively detect AAA in AAA-positive screened individuals was found to be highly sensitive and suitable for detecting AAA prior to ultrasound screening.[9]

The longer the period of time that passes between the prior 3D scan and the NAAASP screening date, the less confident one can be of a normal historical 3D scan, excluding a present-day AAA. Whilst no study has specifically evaluated this question, there are many studies of AAA growth rates in the literature.[10–12] In a poll of

10 vascular consultants in our department, most would be confident that a normal 3D scan within the last three years would be sufficiently contemporary to negate the need for further screening. There is some support for this time frame from similar studies.[9] For the purposes of the data collection for this study, we doubled this time frame to six years.

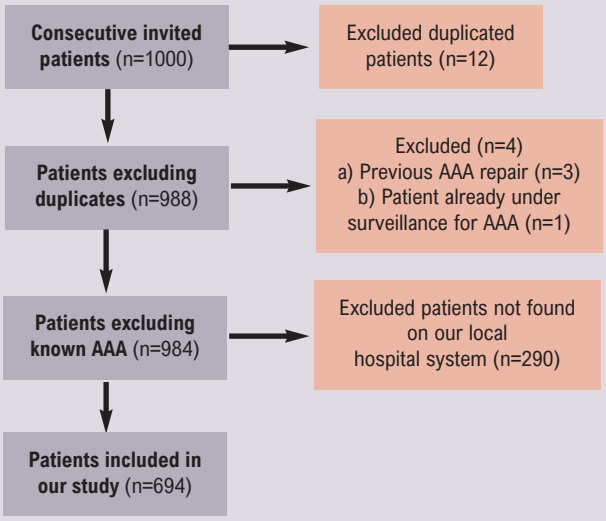
In this study we quantify the percentage of men invited to the NAAASP within our local programme with a suitable previous CT or MRI scan in each of the past six years. The results of this study could suggest ways in which the NAAASP could become more efficient and cost-effective in light of the changing epidemiology of AAA at screening.

Methods

For this retrospective observational study we evaluated 1000 consecutive men invited to the NAAASP in the Cambridgeshire screening programme from late 2022 to 2023. Of these 1000 patients, duplicates and previously diagnosed AAAs were excluded. A number of patients did not have records in the local hospital system and were also excluded. This left 694 patients for evaluation (see Figure 1). Hospital radiology systems were interrogated to identify those men who had had a previous CT or MRI scan within the last six years of their NAAASP screening date. The actual imaging of these scans (not just the reports) was reviewed by a fourth-year medical student trained in aortic assessment. Measurements of the outer-to-outer diameter were taken on the axial view to confirm that the aorta could be visualised and that an AAA was not present. Abdominal ultrasound was not used as the aorta is not typically imaged for dedicated scans of other abdominal organ systems, recording of images is variable, and the operator dependency of this test makes it too subjective.

For patients with prior 3D scans, the date was compared with the NAAASP screening date to calculate the time interval. Only the most recent 3D scan performed prior to each patient's screening attendance was documented; any additional prior scans were disregarded. For men who did not attend their screening appointment and therefore had no actual screening date, the date that screening would have taken place was used instead.

Figure 1 Flow chart of patients excluded from the study. AAA, abdominal aortic aneurysm.



Results

Of 694 consecutive invited men, 82 (11.82%) had had at least one previous CT or MRI scan within the past six years, with the abdominal aorta visible and measurable (Table 1).

The cost of delivering the NAAASP programme was ascertained from NHS tariff data 2022–23. NHS tariff reimburses administrative costs (£1.93) and scanning costs (£36.75) on a per-patient basis (CUH local tariff reimbursement rate correct as of 2024). For the year 2022–2023 the local screening programme invited 6,703 men. We assumed that the administrative costs

Table 1 Number of patients with their most recent 3D scan within X number of years and as a percentage and cummulative percentage of the total study population.

3D imaging within X years prior to screening	Total number of patients	Percentage of total population (%)	Cumulative percentage (%)
X = 1	19	2.74	2.74
X = 2	18	2.59	5.33
X = 3	11	1.59	6.92
X = 4	12	1.73	8.65
X = 5	8	1.15	9.80
X = 6	14	2.02	11.82
Total	82		

Table 2 Potential yearly cost savings in the Cambridgshire region from considering previous patient scans within each year up to 6 years prior to screening.

Considering scans within X years	Potential cost savings
X = 1	£6,749.59
X = 2	£13,129.67
X = 3	£17,046.40
X = 4	£21,308.00
X = 5	£24,140.85
X = 6	£29,116.83

Note: Gross savings based on avoided ultrasound scans (£36.75/patient). Net savings will be lower once the cost of expert clinical evaluation of the scans is deducted. It is important to clarify that the estimated cost savings should be interpreted as the value of reclaimed clinical capacity rather than a direct reduction in programme budgets. Since staff and venue costs in the NAAASP are largely fixed, the use of historical 3D imaging allows these resources to be used more efficiently. Rather than simply reducing regional funding, this approach ensures that limited clinical slots and technician time are reserved for those without alternative contemporary data, thereby improving the overall yield and cost-effectiveness of the programme.

(£1.93) would not be saved as time would be required to look up the patient to check if they have had any previous 3D scan and to send out correspondence, whether a further scan is required or not. Estimated cost savings based strictly on the reduced number of ultrasound scans are shown in Table 2. In terms of operational workload, applying these prevalence rates to the total invited cohort of 6,703 men indicates a potential reduction of approximately 464 screening appointments annually if a three-year window is used for reviewing previous scans.

Discussion

To be satisfactory for the screening objective of excluding an AAA, imaging needs to be of sufficient quality and it needs to be sufficiently contemporary. In our cohort of 694 men invited for screening, 48 (7%) had a suitable CT or MRI scan within three years (Table 1). CT[9] and MRI8 have proven sufficient sensitivity for excluding AAA. Three years was selected as a pragmatic time frame based on data of AAA growth and face validity from a local expert consensus. If a longer time frame is used, then the number of scanned individuals increases to around 10% at five years. However, this comes at the risk of missing new AAAs that have developed between time points. Further studies are required to evaluate what time frame between prior 3D imaging and the intended screening date could be confidently used within an acceptable envelope of risk.

Using scans within three years of the screening date would save around £17,000 per annum in ultrasound scans for the local Cambridgeshire NAAASP programme.

Beyond the financial implications, using pre-existing 3D scans within a three-year window would reduce the programme's clinical workload by approximately 464 ultrasound appointments per year in the Cambridgeshire region alone. This reduction in appointment volume would release capacity within the screening programme and reduce the burden on clinical screening staff.

Nationally, in the year 1 April 2022 to 31 March 2023 approximately 314,900 men were offered AAA screening.[7] Taking the cost of an abdominal ultrasound scan for AAA to be £36.75 and assuming the distribution of recent 3D scans nationally is the same as in our study cohort, approximately 21,791 men would have had a previous 3D scan within three years of their screening date. This equates to a national reduction of 21,791 screening appointments and £800,000 in saved ultrasound screening slots.

While these figures represent gross savings based on avoided ultrasound scan fees, we acknowledge that implementing this model involves a shift in labour costs. The administration time required to search for existing 3D imaging is anticipated to be cost-neutral as it can be performed within the existing time allocated for patient look-up and screening appointment booking. However, we recognise that a net saving must account for the clinical cost of an appropriately trained professional such as a radiologist to robustly evaluate and measure the aorta on prior 3D scans. As this study serves as a proof of concept, these estimated savings should be viewed as the value of reclaimed clinical capacity. By identifying men who do not require a physical appointment, programmes can optimise the use of physical scan slots and ensure that high-cost clinical resources are prioritised for those without alternative contemporary imaging.

Possible ways of implementing the results of this study

Implementing this in clinical practice requires a few steps:

1. Administrative search for prior suitable 3D imaging on a per-patient basis.
2. Trained assessment of 3D imaging and measurement of the maximal dimensions of the abdominal aorta.
3. Reporting the findings and inviting or excluding the patient from further screening.

Steps 1 and 3 can be performed by non-clinically trained personnel or may even possibly be automated in the future by a suitably trained AI algorithm. Step 2, however, requires an appropriately trained individual to accurately measure the abdominal aorta, although this also may potentially be deliverable by AI in the future. These steps have costs associated with them that, as mentioned, will likely reduce our previously estimated cost savings.

An alternative way in which this could be implemented would be to somehow mandate the reporting of aortic size in all 3D scans of all men aged over 60 years so that future searches could be conducted entirely by non-clinically trained individuals. This, however, has its own associated cost and, in practical terms, it would be near impossible to guarantee 100% compliance from reporters.

One way the findings of this study can be immediately implemented in the clinical setting (and indeed this is something that is being piloted in Cambridgeshire) is to search for prior 3D imaging for patients who did not attend their first screening appointment. This can be done by the screener in the 'lost time' during the did not attend appointment. Where this is found, the screening appointment is not consequently wasted and the ascertainment is improved. This does, however, require an amount of additional subsequent input from a clinically trained staff member to evaluate the 3D scan.

Study limitations

A limitation of this study was the small sample size of 694 men and also the fact that these men were all within a single geographical region. 3D imaging rates may vary around the country, which may make our findings more or less applicable when extrapolated to a national cohort.

How far back in time to accept a 3D scan to confidently exclude an AAA today is uncertain. Based on a focused discussion with 10 UK vascular consultants, three years was considered an acceptable limit, giving face-validity to our methodology. Beyond this, there was less confidence in the reliability of historical scans. This tallies with the limited available literature.[9] Further studies are required to evaluate the reliability of historical scans to exclude a

KEY MESSAGES

- 7% of men invited to the NAAASP in Cambridgeshire have had prior 3D imaging in the last three years, which is adequate to exclude an AAA.
- This pre-existing data could be used to potentially reduce costs by avoiding undertaking unnecessary scans.
- Such data can be used immediately by screening units for patients who otherwise did not attend to improve overall ascertainment.

contemporary AAA and to consider how old is too old to reliably exclude an AAA.

Conclusion

Pre-existing 3D scans may be used to adequately screen for AAA in 7% of the population, obviating the need for an additional dedicated ultrasound scan. If this data can be identified and evaluated in a cost-effective manner, then this could result in cost savings for the NAAASP. Use of this data would also increase the coverage rate by screening men who would otherwise not attend.

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QUALITY IMPROVEMENT PROJECT

Improving vascular referral coordination through live documentation in a hub-and-spoke system

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Plain English Summary

Why we undertook the work: Vascular patients are often reviewed in different hospitals within a hub-and-spoke network. This can make it difficult for teams to share information consistently, which may lead to unclear follow-up plans and incomplete documentation. We wanted to improve how referral information and management decisions were recorded and shared across the vascular team.

What we did: We introduced a live shared documentation sheet on a secure cloud platform. Clinicians at both the main vascular centre and spoke hospitals used this sheet to record patient referrals and management outcomes. We compared documentation before and after adding a structured 'Outcome' column.

What we found: Before introducing the Outcome column, only 47% of patients had a documented management outcome. After the change this increased to 85.2%, and no patients had missing follow-up documentation.

What this means: A simple secure shared digital tool can improve the completeness and visibility of documented management decisions across hospital sites. Continued staff engagement is important to maintain these improvements over time.

Abstract

Introduction: The centralisation of vascular services within the National Health Service (NHS) has improved outcomes for complex procedures by concentrating expertise within high-volume centres. However, hub-and-spoke models can introduce challenges in maintaining consistent communication and documentation across sites. This study evaluated a live cloud-based documentation system designed to improve the visibility of referral outcomes within a regional vascular network.

Methods: This quality improvement project comprised two retrospective review cycles of vascular referrals recorded on a shared Microsoft Teams-hosted spreadsheet. The first cycle analysed referrals from December 2023 and the second from August 2024. Recorded variables included patient demographics, referral source, urgency category and responsible clinician. In July 2024 a structured 'Outcome' field was introduced to document management decisions and follow-up plans. Clinicians were instructed to complete this field immediately following patient review.

Results: In December 2023, 66 referrals were recorded, with outcome documentation present in 47% of cases and one patient (1.5%) lacking follow-up documentation. In August 2024, 88 referrals were reviewed, with 85.2% containing documented outcomes and no patients with missing follow-up information. These findings demonstrate a marked improvement in the completeness of outcome documentation following introduction of the structured outcome field.

Conclusion: Implementation of a live shared documentation system within an existing NHS-approved platform was associated with improved completeness and visibility of recorded management decisions across a centralised vascular network. Ongoing staff engagement and routine review cycles are essential to sustain documentation quality and system adoption.

Key words: vascular surgery; hub-and-spoke model; communication; digital health; referral pathways

Introduction

Over the past two decades there has been a clear trend in the UK National Health Service (NHS) towards the centralisation of hospital services. In vascular surgery this model typically consists of a central hub for surgical interventions and multiple spoke sites that provide outpatient follow-up and some minor procedures, such as varicose vein treatments and angioplasties.

Clinicians have identified systemic communication deficiencies that negatively affect referral and review processes. These include lost referrals during inter-site transfers, aligning with the findings of Hakeem and Najem who reported delays in referrals and treatments across a vascular network and emphasised the need for ongoing monitoring to mitigate these inefficiencies.[1]

Such communication lapses extend beyond referrals. Wariyapola *et al* highlighted significant deficiencies in discharge communication during patient transfers between hub and spoke centres. They recommended dedicated discharge coordinators as a potential solution to enhance care transitions.[2]

Centralisation in vascular surgery is supported by robust evidence showing a volume–outcome relationship. High-volume centres, particularly in aortic aneurysm repairs, consistently achieve superior results. Similar patterns are observed in procedures such as carotid endarterectomy and critical limb ischaemia management. These centres benefit from multidisciplinary care and specialised infrastructure, which translates into improved outcomes.[3]

International data from over 9000 ruptured aneurysm repairs showed a nearly 10% mortality difference between high- and low-volume centres, consistent with earlier UK findings where the gap once reached 24%.[4,5]

While this structure promotes optimal clinical outcomes, the literature repeatedly highlights communication gaps that impair patient care and cause delays. To address this, we developed a live documentation tool aimed at improving follow-up coordination.

Method

A quality improvement project (QIP) using retrospective review was conducted, including all patients prospectively added to a centralised vascular referral list during December 2023, with a subsequent review in August 2024. The referral system, implemented in October 2023, was hosted on a Microsoft Teams. Access was approved by the hospital Information Technology department and granted to relevant staff across both hub and spoke sites, including vascular clinicians, administrative personnel and the hospital bed management team. Microsoft Office 365 for the NHS provides secure cloud-based applications within NHS governance frameworks, facilitating multidisciplinary collaboration and data sharing.

The referral list was structured as a Microsoft Excel spreadsheet designed to capture comprehensive patient information. Recorded fields included hospital number, NHS number, patient name, date of birth, contact details, referring clinician, spoke site, on-call consultant of the week, presenting symptoms, urgency category, referral location (emergency department, inpatient ward or outpatient clinic) and a general notes section.

Vascular clinicians were instructed to record all referrals requiring urgent vascular review or potential admission, based on referring clinician assessment in line with local practice. Patients admitted as emergencies directly via emergency departments or requiring immediate inter-hospital transfer were excluded as these cases were communicated directly to the on-call vascular team. Elective admissions were managed through a separate scheduling pathway.

Within the vascular network, hub-and-spoke sites operate on different electronic documentation systems. The referral spreadsheet was operationally maintained by the administrative team, who reviewed entries daily to support bed management and patient tracking at the hub site. However, outcomes from clinical reviews conducted at the hub were not consistently visible to spoke teams, resulting in potential communication gaps. This limitation was highlighted during a consultant governance meeting.

To address this, the referral list was modified in July 2024. A structured 'Outcome' column was introduced to enable reviewing clinicians to document management decisions and follow-up plans in real time, with the aim of improving transparency and continuity of information across the network.

Results

In December 2023 a total of 66 patients were referred by vascular clinicians to the hub for urgent assessment or potential vascular admission. Although the shared referral list supported referral tracking, documented outcome plans were present in only 47% of cases within the general notes section, and one patient (1.5%) had incomplete follow-up documentation. All other segments in the spreadsheet were completed.

In response to these findings, a structured 'Outcome' column was introduced in July 2024 and clinicians were instructed to document management decisions and follow-up plans immediately after patient review.

A subsequent audit conducted in August 2024 evaluated 88 urgent referrals. Outcome documentation improved, with 75 of 88 cases (85.2%) containing completed outcome entries and no patients had missing follow-up documentation. No urgent referrals were excluded or misclassified in either audit cycle. These findings demonstrate a marked improvement in the completeness and visibility of documented management decisions across the network.

Discussion

Vascular surgery has evolved rapidly over the past two decades, with increasing adoption of collaborative and technology-supported models of care. Multidisciplinary team (MDT) meetings involving vascular surgeons and interventional radiologists are now central to clinical decision-making. During the COVID-19 pandemic, these meetings transitioned to online platforms such as Microsoft Teams and have since become embedded in routine practice.[6]

Vascular patients frequently require long-term follow-up following intervention. Local follow-up within spoke hospitals improves accessibility and patient convenience. However, as Mungall highlighted,[7] centralisation can inadvertently reduce access for rural populations despite its clinical benefits. From a clinician perspective, the hub-and-spoke model supports remote assessment and surgical planning but depends heavily on reliable information exchange.

Communication delays remain a recognised limitation of centralised vascular networks. Hakeem and Najem reported increasing referral delays from spoke sites and emphasised the importance of MDT involvement at peripheral centres to improve consistency of care.[1] These findings reinforce the need for practical low-cost solutions that enhance visibility of patient management decisions across sites.

Our model addresses these challenges by using an existing NHS-approved platform (Microsoft Teams) to host a shared cloud-based Excel dataset accessible to all vascular team members across the three hospitals within our network. Unlike bespoke electronic referral systems, which often require additional licensing or development costs, this approach leverages existing digital infrastructure. Similar studies have shown that electronic referral and documentation systems can reduce operational costs compared with traditional or custom-built platforms.[8]

Importantly, our system functions as a shared live dataset rather than a formal e-referral platform. It enables real-time documentation of management decisions and follow-up plans, improving the visibility of clinical information for both hub and spoke teams including situations where patient circumstances change such as non-attendance or clinic review.

Although the second QIP cycle demonstrated substantial improvement in outcome documentation, a small proportion of entries remained incomplete. This is consistent with previously reported challenges during the early adoption of digital systems and highlights the importance of ongoing staff engagement and reinforcement.[9] Targeted education informed by audit feedback has been shown to improve compliance and data completeness, and our experience supports this approach.[10]

The use of a shared electronic system also reduces reliance on paper-based communication, which is known to be vulnerable to loss and unauthorised access. Multiple NHS reports have identified paper records as a frequent source of data breaches. In contrast, the present system operates within a secure access-restricted environment, allowing only authorised vascular team members to enter or modify patient information.[11]

While this study represents a single-network pilot evaluation with a modest sample size, the simplicity, low cost and ease of implementation make the model readily transferable to other NHS vascular and surgical networks.

Conclusion

The centralisation of vascular services has been associated with improved clinical outcomes through the concentration of expertise and resources within specialised centres. However, this model also introduces challenges in maintaining consistent communication across hub-and-spoke networks. Our evaluation demonstrates that a live cloud-based documentation system provides a practical and cost-effective method for improving the visibility of patient management decisions across sites. The introduction of a structured outcome field was associated with a substantial improvement in the completeness of outcome documentation. Although missed follow-ups were uncommon in both QIP cycles, the intervention enhanced data completeness and transparency within the referral process.

Initial implementation required staff reinforcement and training; however, subsequent QIP findings suggest that sustained engagement and integration into routine clinical workflows can support long-term adoption. Ongoing education, regular audit cycles and leadership endorsement will remain essential to maintain documentation quality. Overall, this study indicates that simple digital solutions, when implemented within existing NHS-approved platforms, can support more reliable information sharing within centralised vascular networks without the need for additional bespoke systems.

KEY MESSAGES

- A simple live documentation tool hosted on Microsoft Teams improved the completeness and visibility of referral outcome documentation across a vascular hub-and-spoke network.
- Documented outcomes increased from 47% to 85.2% after introducing a structured 'Outcome' field.
- No patients were missed during follow-up after implementation.
- The approach is low-cost, uses existing NHS digital infrastructure and is easily reproducible.
- Ongoing staff engagement and regular audits are essential to maintain improvements.

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Ethics: This project was conducted as a service evaluation. According to NHS and institutional policy, formal ethical approval was not required.

Permissions: No copyrighted material, patient images, or identifiable information were used. No permissions required.

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PROTOCOL

Surgical wound healing by secondary intention versus primary and delayed primary closure: systematic review protocol

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Plain English Summary

Why we are undertaking this research: After certain operations, wounds are intentionally left open to heal from the bottom up. This is known as surgical wound healing by secondary intention (SWHSI). SWHSI can take a long time to heal, need frequent dressing changes, greatly impact quality of life and may require further interventions. However, it may be possible to close the wound at the time of surgery (known as primary closure) or some time later (known as delayed primary closure). We don't know which of these method leads to the best outcomes for patients.

What we aim to do: We will bring together and analyse the best evidence (randomised controlled trials) in adults that compare leaving the wound open to heal by secondary intention and wound closure (either primary or delayed primary). We will search major databases measuring time to wound healing, and how many wounds are healed at 6 and 12 months. Other outcomes will also be measured, including infection, pain, need for antibiotics, hospital admission, changes in treatment or re-operation, progression to amputation, death, quality of life and healthcare use. We will combine and analyse the results from all the different trials, and assess the quality and certainty of the trials. The findings of this study should clarify whether leaving a surgical wound open to heal from the bottom up is better than immediate closure or delayed wound closure, support better decision making, inform guidelines and highlight where further research is required.

Abstract

Background: Surgical wound healing by secondary intention (SWHSI), where wounds remain open after an operation and are allowed to close gradually from the bottom upwards, is common, resource-intensive and associated with prolonged healing durations and complications. Alternative closure methods such as primary closure and delayed primary closure may offer better outcomes; however, the current evidence base remains uncertain with no formalised guidelines to aid decision making. This study aims to determine the efficacy of alternative closure methods.

Methods: This is a protocol for a systematic review and meta-analysis. Databases that will be searched include MEDLINE, Embase, CINAHL and CENTRAL with no date restrictions applied. Only randomised controlled trials enrolling adults aged 18 and above published in the English language will be included. Two reviewers will independently screen and assess the eligibility of manuscripts and extract data using a template, with disagreements being resolved by consensus or a third reviewer. Risk of bias will be evaluated using the Cochrane Risk of Bias 2.0 (RoB 2). A meta-analysis will be carried out if appropriate; if not, a narrative synthesis will be provided. If substantial heterogeneity is observed, subgroup analysis will be performed to explore potential sources of variability.

Discussion: This study will aim to synthesise the best available evidence comparing SWHSI with primary and delayed primary closure. The results from this study aim to support decision making, inform guidelines and highlight where further research is required.

Key words: surgical wounds, healing by secondary intention, healing by primary intention, delayed primary closure

Prospero registration: CRD420251070682

Background

Every year 4.4 million surgical procedures are undertaken under the National Health Service (NHS) in England.[1] Incisions made during these procedures are ideally closed immediately after surgery, known as primary closure or healing by primary intent. In some circumstances the incision is left open and allowed to heal from the base upwards through granulation, followed by re-epithelialisation and contraction known as healing by secondary intent.[2] Surgical wound healing by secondary intention (SWHSI) may be indicated where primary closure is not feasible due to being dirty or contaminated, containing active infection, having insufficient tissue for closure, or where a wound has subsequently dehisced following primary closure.[3,4]

SWHSIs are relatively common, affecting 4.1 per 10,000 and account for approximately one-quarter of all surgical wounds.[3,5] Among all the procedures involving SWHSI, abdominal wounds (33.6%) and lower extremity wounds are the most common, often following colorectal (42.8%) and vascular (11.8%) surgeries.[5] SWHSIs carry a considerable economic burden estimated to be approximately £1501–£2383 per patient per month. Costs are predominantly driven by factors including increased rates of hospital re-admission at 24.7%, increased rates of infection at 32.1% and requirement for further interventions at 16.8%.[3,5,6] SWHSIs also lead to significantly longer healing times with a median time of approximately 3 months, with only 81.4% of wounds achieving closure within 12 months along with reduced tissue strength and poorer cosmetic outcomes.[7–9] A cohort study in 2019 demonstrated that the management of SWHSIs remains heterogenous, with the most commonly used dressing being hydrofibre or spun hydrocolloid dressings followed by wound contact dressings and negative pressure wound therapy at 41.7%, 32.8% and 29.0%, respectively.[6]

Several surgical techniques may be used as alternatives to SWHSI. A randomised controlled trial in 2025 showed that 34.7% of wounds were classed as clean or clean-contaminated, indicating that they may have been suitable for alternative closure methods.[10] Primary closure, or healing by primary intention, involves the immediate approximation of wound edges using sutures, staples or adhesives and is the most commonly used method for clean wounds.[11] In contaminated wounds, delayed primary closure or healing by tertiary intention may be more suitable and involves leaving wounds open for a period of time post-surgery with dressing changes, before closing the wound with sutures or staples.[12] In contaminated wounds, primary closure was associated with a significantly higher rate of infections, wound dehiscence and a longer hospital stay compared with delayed primary closure.[13–15] However, primary closure eliminates the need for dressing changes and their associated costs along with a shorter hospital stay compared with delayed primary closure.[16]

SWHSIs remain open for many months and frequently require multiple interventions, resulting in significant disease burden to patients and substantial healthcare costs.[17] Therefore, alternative wound closure methods should be considered where possible. The aim of this systematic review is to determine the effectiveness of SWHSI versus primary or delayed primary closure to aid decision-making as well as identify gaps for further research.

Methods

This systematic review is prospectively registered on the International Prospective Register of Systematic Reviews (PROSPERO) database with the reference: CRD420251070682. The Preferred Reporting Items for Systematic Reviews and Meta-analyses Protocols (PRISMA-P) guidelines will be used as a guide for this systematic review protocol.[18]

Search strategy

Databases will include EMBASE, OVID Medline, CINAHL and Cochrane Central Register of Controlled Trials (CENTRAL). There will be no time frame constraints applied to the search.

The search strategy will be developed in conjunction with a certified medical librarian to formulate the search strategy. Search terms will be designed around SWHSI and alternative closure methods using both free-text keywords and medical subject headings to maximise sensitivity.

Search terms will include – but are not limited to – "secondary intention", "secondary intent", "primary closure", "primary intention", "delayed closure", "delayed primary" and "tertiary intention". The preliminary search strategy is attached in the appendix. Randomised controlled trial filters used were obtained from the InterTASC Information Specialists' Sub-Group.[19]

Inclusion/exclusion criteria

Randomised controlled trials published in the English language, comparing surgical wound healing by secondary intention with either primary closure or delayed primary closure will be included. Papers that compare different management options for SWHSIs that received closure at a later date will also be included.

Exclusion criteria include wounds left open without the intention of healing (such as stoma and gastrostomy sites), surgery that does not involve an incision on the skin surface, split skin donor graft sites, nail avulsions, dermal substitute use, oral surgeries such as cavities from dental extractions, staged closure methods, stoma reversal wounds, operations of the eye, wounds from minor dermatological or plastic procedures (such as removal of warts, skin tags and punch biopsies) and chronic wounds such as pressure ulcers or foot ulcers that are non-surgical in origin (diabetic foot ulcers that underwent debridement in theatre will be included).

Only trials with participants over the age of 18 will be included. SWHSIs may be planned through preoperative recruitment or in patients with a pre-existing SWHSI.

Study selection

The Covidence web tool will be used for study screening, selection,

data extraction and quality assessment.[20] Duplicates will be removed manually after automatic duplicate identification. Two authors will independently screen all titles and abstracts to remove those that do not fit the inclusion criteria. The remaining full-text manuscripts will then be reviewed and data extracted following the same process. Any disagreements will be resolved through mutual consensus between the two review authors, or by arbitration by a third reviewer if required.

Data extraction and management

A standardised data extraction template developed by the review team will be used. Patient demographics, interventions, comparators, wound location, operation type and study outcomes will be collected. Conflicts of interest, funding source, specialty, healthcare setting, study design, sample size and other biases will also be collected where available. Raw data will be extracted from the manuscripts into the Covidence built-in data extraction template and Review Manager (RevMan®).[20]

Assessment of methodological quality

The Cochrane Risk of Bias 2.0 (RoB 2) tool for randomised trials will be used to evaluate risk of bias in this study rated as 'high', 'low' or 'some concerns'. Risk of bias due to missing results will be assessed if a minimum of 10 studies are included for meta-analysis through funnel plots and Egger's test.

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system will be implemented to evaluate the degree of certainty of evidence supporting each outcome, which may be labelled as either 'very low', 'low', 'moderate' or 'high'. Two reviewers will conduct the risk of bias assessment independently, with any disagreements resolved by mutual consensus or arbitration by a third reviewer.

Outcomes

There will be two primary outcomes for this systematic review. The first is time to healing, defined as time to complete re-epithelialisation of the wound. A large multicentre randomised trial used Kaplan–Meier time-to-event methods over a 12-month follow-up period and demonstrated that healing continues throughout this period, with a substantial proportion of wounds remaining unhealed at 12 months.[10] Accordingly, the second primary outcome will be the proportion of wounds healed at 6 and 12 months post-procedure, representing a milestone at which delayed or non-healing wounds may prompt reassessment, re-intervention, or alternative treatments.

Secondary outcomes will include clinical events as a composite outcome, which are: requirement for antibiotic treatments, rate of hospital admission or discharge, treatment status including reasons for dressing or treatment failure or change, re-operation rates including closure interventions, progression to amputation and death. We will also evaluate wound infection rates, wound pain, quality of life and resource usage such as consultations, support and other costs and frequency and type of wound dressing changes.[10]

KEY MESSAGES

- SWHSIs are common and require long periods of time to heal, carry increased risk of infection and re-admission, greatly impact quality of life and may require further interventions.
- Currently, there is no clear consensus regarding the optimal management of SWHSIs, hence alternative methods should be investigated.
- This systematic review protocol aims to assess the healing rates along with the listed secondary outcomes for SWHSIs compared with primary and delayed primary closure.

Statistical analysis

Meta-analyses will be conducted using RevMan® for studies with comparable methodologies and outcomes. Continuous outcomes will be reported using mean differences or standardised mean differences (SMD) depending on uniformity. Dichotomous outcomes such as antibiotic treatments and death will be presented as risk ratios (RR) or odds ratios (OR) with their respective 95% confidence intervals (CI). Time to event outcomes will be reported using hazard ratios (HR) with their corresponding 95% CIs. Separate meta-analyses will be conducted where feasible, otherwise a narrative synthesis will be provided.

Heterogeneity will be assessed using the X^2 test and the I^2 statistic if clinical homogeneity criteria are acceptable. A random-effects model will likely be implemented, considering the anticipated heterogeneity in surgical indication, wound features and interventions. If heterogeneity is minimal, a fixed effects model will be implemented. The I^2 statistic cut-off for heterogeneity that will be used is 60%. If substantial heterogeneity is observed, subgroup analysis will be performed to explore potential sources of variability. Stratification will be based on key clinical features such as surgical wound characteristics, closure method and level of contamination or presence of infection. Additionally, to mitigate the anticipated heterogeneity of results, we will aim to stratify the results by operation type and wound location where extracted data permit, allowing for context-specific interpretation of results.

Discussion

There is no clinical consensus on the management of SWHSIs, which reflects a lack of evidence in the literature. A qualitative study in 2020 showed that clinicians had variable knowledge of SWHSI treatments and frequently opted for negative pressure wound therapy, despite a lack of evidence supporting its use.[6]

There is evidence to suggest that a high proportion of SWHSIs were suitable for alternative methods of wound closure.[10] To date, there are no comprehensive reviews comparing SWHSIs to primary

or delayed primary closure. A robust look at the evidence in this area will help inform future practice and improve patient outcomes surrounding wound healing.

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CASE REPORT

New onset arteriovenous malformations in adults: a case series of caution

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Abstract

Introduction: New onset arteriovenous malformation (AVM) in adulthood requires a high index of clinical suspicion. The misdiagnosis of vascular soft tissue lesions as AVMs is relatively common, resulting in delays to definitive diagnosis and management. We present four recent 'AVM referrals' which were neoplastic and propose some clinical considerations to facilitate development of a care pathway for AVM referrals.

Case reports: Four patients over a 6-month period were referred with 'an AVM' following clinical and ultrasound assessment. Ultimately these lesions were diagnosed to be neoplastic, including a Merkel cell carcinoma, an atypical fibroxanthoma with sarcomatous features, and two cases of relapsed marginal zone lymphoma.

Discussion: These cases demonstrate a range of features which are atypical for AVM. Atypical clinical features include sudden onset, rapid growth, pain or haematological malignancy in earlier life. Atypical ultrasound findings include failure to identify clear feeding vessels or a central nidus, and simple reporting of lesion vascularity. There is significant variation in ultrasound practices for vascular soft tissue lesions which do not follow a standardised protocol. Clinical decision making may be facilitated by complementary imaging and histological tissue sampling.

Conclusion: New onset AVM in adulthood with atypical clinical and ultrasound features should raise suspicion for malignancy. Such vascular soft tissue lesions require urgent investigation within a multidisciplinary setting to avoid delays in diagnosis and treatment.

Key words: arteriovenous malformation (AVM), vascular-appearing soft tissue lesions, malignancy mimicking AVM, ultrasound interpretation

Introduction

Arteriovenous malformations (AVMs) are rare vascular anomalies characterised by shunting of arterial blood into the venous system without an intervening capillary bed, leading to a high-flow pressure system. These malformations can manifest in various tissues and organs, presenting with a wide spectrum of clinical signs including pulsation, thrills, bruits and elevated local temperature.[1,2] A wide range of malignant soft tissue tumours mimic AVMs due to associated neovascularisation or vascular invasion on ultrasound, leading to inappropriate referral and management plans with 40% of soft tissue sarcomas being misdiagnosed.[3] This series outlines four recent referrals for suspected AVM in whom histopathological examination confirmed malignancy. These cases emphasise the need for clinicians to consider a broader differential diagnosis when encountering atypical vascular-appearing lesions labelled as AVM. All cases presented were fully counselled, consented and, in liaison with the appropriate multidisciplinary team (MDT), the lesions were excised (or biopsied) and sent for histological assessment. All cases have provided consent for use of their history and images for learning purposes.

Case reports

Case 1

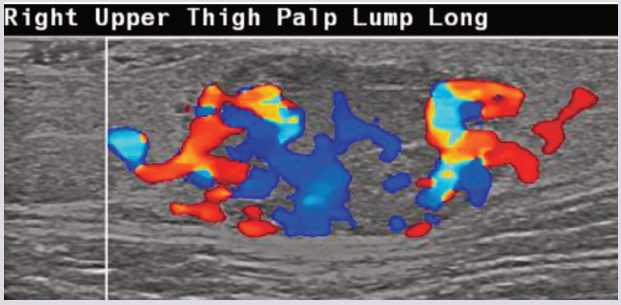
A 54-year-old man presented with an 18-month history of an enlarging painful lesion on the lateral right thigh (Figure 1). There were no systemic symptoms or lymphadenopathy. Handheld doppler examination identified an arterial signal adjacent to the lesion. Ultrasound was reported as a well circumscribed, hypoechoic, solid homogenous, hypervascular soft tissue lesion with arterial and venous flow seen (Figure 2).

Subsequent CT indicated an arterial supply (profunda branch) without evidence of invasion or other abnormality identified, which was summarised as likely to be an AVM.

He was subsequently referred to the vascular service where excision biopsy was undertaken.

Figure 1 Photo of case 1 skin lesion.

Figure 2 Screenshot of duplex scan of case 1 lesion.



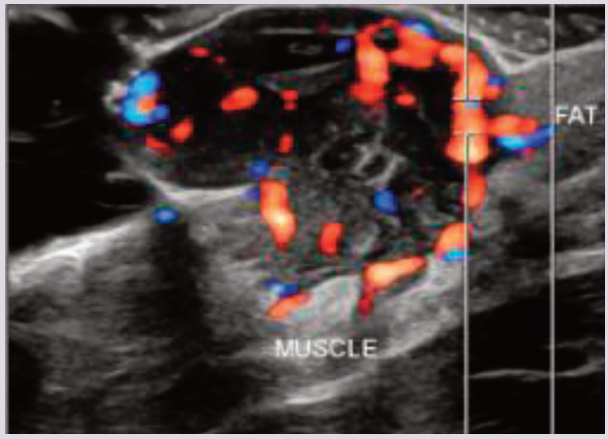
Histology revealed a lobulated necrotising high-grade Merkel cell carcinoma with close peripheral and deep margins, staged as T2M0N0. He is receiving radiotherapy following marginal excision to the original lesion site.

Case 2

A 35-year-old man presented with a 12-month history of an enlarging blue-tinged nodule on the upper limb, reporting bleeding on contact, but without systemic symptoms (Figure 3). Ultrasound demonstrated an 18×14×15 mm well-defined hypoechoic lesion within the subcutaneous fat, with moderate arterial flow and suspected feeder vessels, reported as having features suggestive of a haemangioma or AVM (Figure 4). Referral to the community dermatology service was redirected to general surgery who, having reviewed the ultrasound report, redirected him to vascular services as a probable AVM.

Figure 3 Photo of case 2 skin lesion.

Figure 4 Screenshot of duplex scan of case 2 lesion.

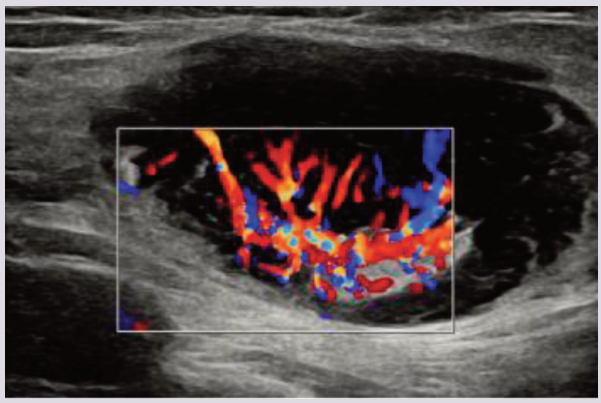


Given diagnostic concern, excision biopsy was undertaken with margins. Histology reported an excoriated atypical spindle cell tumour infiltrating into the subcutaneous tissue, showing high mitotic activity. Immunohistochemistry was negative for melanoma, epithelial and vascular markers but positive for CD10, suggestive of atypical fibroxanthoma but, due to deep infiltrative growth, significant atypia and location, a diagnosis of dermal sarcoma was favoured. At follow-up, a new skin lesion with similar clinical features has been identified on the lower limb which is pending further excision biopsy in addition to cross-sectional imaging for staging and decision on further management.

Case 3

A 75-year-old man with a history of B-cell lymphoma and prior splenectomy (for immune thrombocytopenic purpura) was referred with an enlarging posterior right thigh lesion. Ultrasound showed a 44×16×24 mm ill-defined heterogeneous lesion with serpiginous internal anechoic areas and marked vascularity (Figure 5).

Figure 5 Screenshot of duplex scan of case 3 lesion.



At review, a further lesion was clinically identified in the medial thigh corresponding to a 17 mm irregular hypervascular lymph node. Subsequent MRI (Figure 6) and CT positron emission tomographic (PET) imaging revealed a 44 mm mesenteric mass in addition to clinically identified lower limb lymph nodes with fluoro-deoxyglucose (FDG) avid activity (Figures 7 & 8).

Core biopsy showed complete architectural effacement and diffuse proliferation of small to medium-sized CD20+ and CD79a+ B-lymphocytes with a low Ki-67 proliferation index, consistent with low-grade B-cell lymphoma, favouring nodal involvement by marginal zone lymphoma. Treatment with chlorambucil and rituximab was initiated by the MDT and achieved a stable response.

Figure 6 MRI of the thigh of case 3 highlighting thigh lesion.

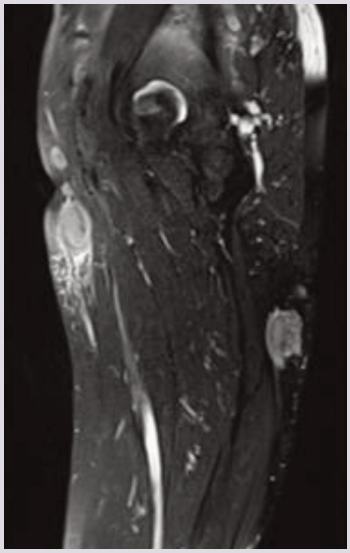


Figure 7 PET CT scan of case 3 showing fluorodeoxyglucose (FDG) avid activity in the groin.

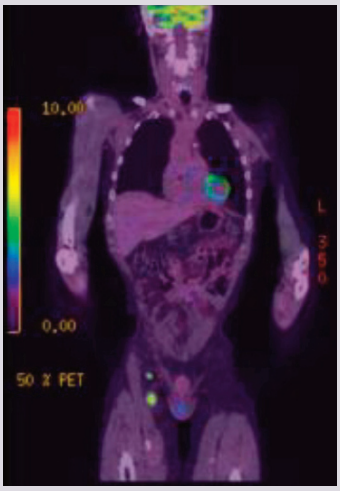
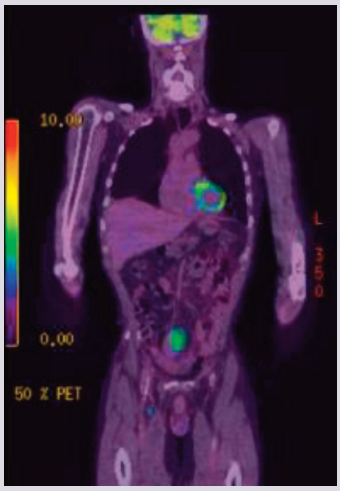


Figure 8 PET CT scan of case 3 showing fluorodeoxyglucose (FDG) avid activity in the mesentery.



Case 4

A 76-year-old man with a past history of extranodal marginal zone B-cell lymphoma treated with radiotherapy in 2016 presented with an enlarging left groin mass. Ultrasound showed a 90×22×41 mm fusiform hypoechoic cuff centred around the great saphenous vein. The lesion was reported as being hypervascular but was not affecting flow through the vein (see Figures 9 and 10). The sonographer felt an AVM was possible, prompting forward referral.

Figure 9 Ultrasound image of case 4 lesion with the great saphenous vein visible through the lesion.

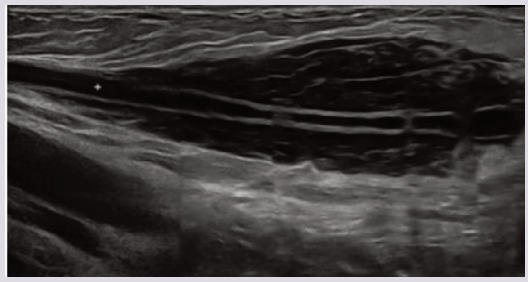
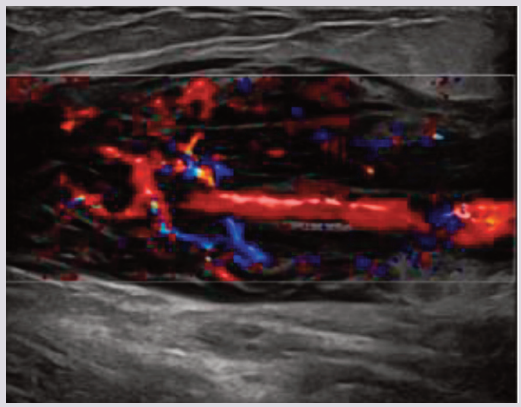


Figure 10 Duplex scan of case 4 lesion with hypervascularity.



At review, in addition to the left groin mass, two lateral thigh lesions were identified. The patient was otherwise clinically well with no systemic symptoms. Subsequent MRI confirmed an 11 cm subcutaneous mass encasing the great saphenous vein without muscular invasion. A PET-CT scan showed FDG avid activity in the thigh lesions as well as the abdomen and pelvis (see Figures 11 and 12).

Figure 11 PET CT scan of case 4 showing fluorodeoxyglucose (FDG) avid activity in the groin.

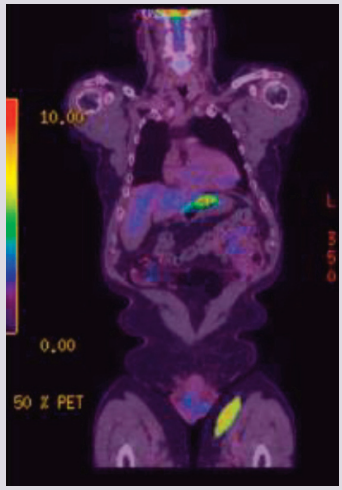
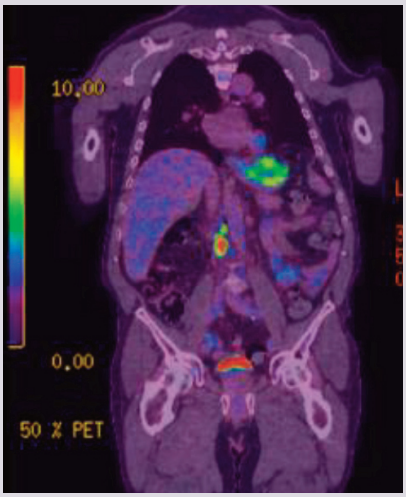


Figure 12 PET CT scan of case 4 showing fluorodeoxyglucose (FDG) avid activity in the abdomen and pelvis.



Core biopsy of the thigh lesion showed architectural effacement of lymphoid tissue, suspicious for marginal zone lymphoma recurrence. He was commenced on cycles of rituximab/ cyclophosphamide/ vincristine/ prednisolone (RCVP) for disease control.

Table 1 Recommendations to improve standardisation, validity and reliability of ultrasound assessment.

Location: in the body, subcutaneous tissue, beyond the fascia, in the muscle, etc

Description: hard/soft, margins, echostructure: homogeneous/inhomogeneous

Measurements: depth x height x width

Surrounding tissues: thickened/non-thickened

Colour Doppler (vascularity)
- Non-vascularised lesion
- Vascularised mass
- Vascular lesion

Spectral analysis: high-flow or low-flow lesion

Impression: lesion as described above that is:
- Typical of a benign ...
- Consistent with a soft tissue neoplasm, but otherwise non-specific
- Not a mass, consistent with ...
- Consistent with lymphadenopathy most likely reactive/metastatic/lymphoma or non-specific

Recommend:
- No further follow-up other than periodic self-examination
- Follow up ultrasound in x weeks
- MRI with contrast
- Ultrasound guided aspiration/biopsy
- Surgical consultation

KEY MESSAGES

- Ultrasound imaging of vascular lesions should have a standardised approach
- Atypical features should raise concern for malignancy
- Cross-sectional imaging and a multidisciplinary team approach are crucial in diagnosing between an arteriovenous malformation and malignancy.

Discussion

This contemporary case series demonstrates the pitfall of new onset 'AVM referrals' when originating from areas of limited clinical experience and reliance on non-protocolised ultrasound reports.

Epidemiological context is important in considering a diagnosis of AVM as most cases present early in life, and new true vascular lesions in adults are more likely to be acquired. Population-based studies suggest the prevalence of true AVMs in adults remains low, reinforcing the need to maintain a broader differential diagnosis in older patients presenting with vascular-appearing soft tissue lesions.[4] Symptoms suggestive of alternative diagnoses to AVM commonly include – but are not limited to – sudden onset (without trauma or intervention), rapid growth ± regression period, bleeding and/or painful at rest and a past history of haematological malignancy.

Due to ease of access, patients referred to secondary care services with a possible AVM have not infrequently undergone ultrasound assessment. However, possibly due to lack of guidelines, ultrasound assessment and reporting is variable. Soft tissue tumours are well known to exhibit increased internal vascularity due to angiogenesis or direct vascular invasion, resulting in ultrasound findings that can mimic AVMs.[3,5,6] This overlap is well-documented, with malignancies including sarcomas and lymphoma being commonly mistaken for benign vascular anomalies.[3,7] Recommendations to improve standardisation, validity and reliability of ultrasound assessment have been recommended (see Table 1).[8,9]

Where imaging is unclear or a high clinical suspicion exists for malignancy, tissue biopsy is critical in an MDT setting.[6,7] Delays in obtaining tissue diagnosis, often due to perceived vascularity or fear of bleeding, can delay timely oncological diagnosis and treatment. Therefore, efficient MDT working across a range of specialities is important in complex or indeterminate cases and permits flexible approaches to ensure responsiveness and holistic care.

The role of advanced imaging modalities such as MRI and PET-CT is increasingly important when lesions exhibit atypical characteristics. PET imaging is particularly valuable in the assessment of marginal zone lymphoma and has been shown to correlate with disease burden and staging, especially in relapsed or extranodal presentations.[10,11] This should be considered early in patient pathways where there is a history of adulthood haematological malignancy.

Classification of true vascular anomalies should be guided by international recommendations into vascular tumours (benign, borderline and malignant) and vascular malformations (fast or slow flow), which provide valuable information and inform decisions regarding further imaging and treatment.[12,13]

Conclusion

A thorough history and clinical examination remain the critical first

step of 'possible AVM' assessment, supported by protocolised ultrasound examination and reporting. Atypical features should raise suspicions of underlying malignancies. In such cases, clinicians should have a low threshold for histological evaluation with complementary cross-sectional imaging, as part of a robust MDT, in order to reduce misdiagnosis and treatment delay.

Conflict of Interest: None.

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CASE REPORT

Explantation of infected kissing iliac stents complicated by acute discitis with aortoiliac reconstruction: a case report

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Abstract

Introduction: Endovascular therapy for aortoiliac occlusive disease (AIOD) has the benefits of being minimally invasive with reliable patency outcomes. The VIABAHN VBX Balloon Expandable Endoprosthesis is widely used for iliac interventions; however, infection of such devices is exceptionally rare and its clinical course poorly characterised.

Case presentation: A 55-year-old man with a history of mucosa-associated lymphoid tissue lymphoma presented with lifestyle-limiting claudication due to left common iliac artery occlusion. Following multidisciplinary team (MDT) review, he underwent successful percutaneous kissing iliac stenting using VBX endoprostheses. One week later he re-presented with new onset back pain and left leg swelling. 18F-fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) demonstrated focal tracer uptake around the left iliac stent with maximum standardised uptake value (SUVmax) 10.6, and blood cultures grew *Staphylococcus epidermidis*. Despite intravenous antibiotics, the pain worsened and repeat PET/CT revealed progression (SUVmax 15.6) and L4 vertebral erosion consistent with discitis and osteomyelitis.

Management and outcome: Following MDT consensus, both stents were explanted and the aortoiliac segment reconstructed in situ with a custom bifurcated graft fashioned from bovine pericardium. Cultures confirmed *S. epidermidis*. Guided by susceptibility testing and European Society for Vascular Surgery recommendations, ceftriaxone (2 g IV daily) and rifampicin (600 mg orally daily) were administered for 10 weeks. Serial MRI demonstrated resolution of the 26 × 19 mm prevertebral abscess and regression of inflammatory changes. At six-month follow-up the patient remained infection-free with restored mobility, reporting only retrograde ejaculation – recognised consequence of open aortic surgery.

Conclusion: This appears to be the first documented infection of a VBX endoprosthesis complicated by early vertebral discitis. Rapid diagnosis through multimodal imaging and coordinated surgical–infectious disease management enabled cure. Clinicians should maintain vigilance for this rare but severe complication, particularly in immunocompromised patients.

Key words: iliac stents, infected grafts, VIABAHN® VBX Balloon Expandable Endoprosthesis, aortoiliac reconstruction.

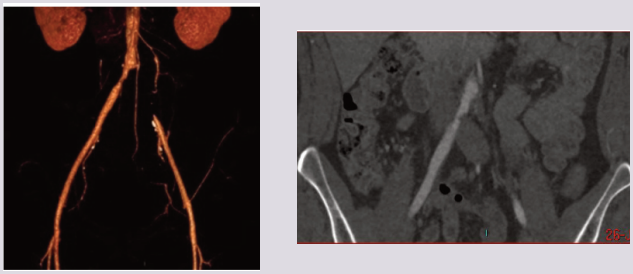
Introduction

Recent advances in endovascular devices, coupled with increased operator experience, have expanded the use of endovascular therapy for treating extensive aortoiliac occlusive disease (AIOD). These procedures are now frequently employed as first-line treatment, largely due to the perception that surgical options remain viable if endovascular approaches fail.[1] Nevertheless, several important questions persist regarding this evolving treatment paradigm. While the theoretical risk of infection associated with vascular endoprosthesis is recognised, the occurrence of such events with iliac stents remains exceedingly rare and data on their incidence and outcomes are limited.

Case report

We report a case of a 55-year-old man who

Figure 1 CT angiography showing left common iliac artery (CIA) total occlusion with right CIA stenosis.

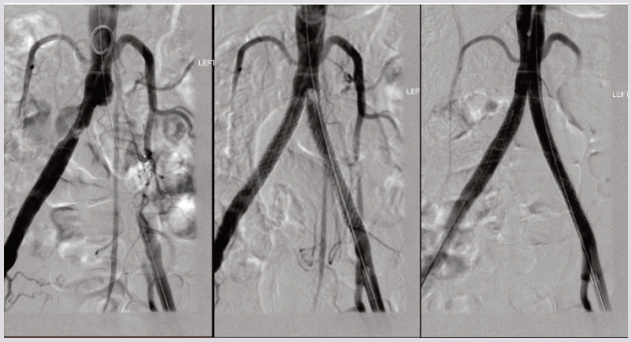


presented with progressive life disabling claudication involving the buttocks and calves not responsive to best medical therapy and supervised exercise. His past medical history was notable for chronic obstructive pulmonary disease, peripheral vascular disease and stage IVSE terminal ileum mucosa-associated lymphoid tissue (MALT) lymphoma, previously treated with six cycles of rituximab, cyclophosphamide, vincristine sulfate and prednisone, completed one year prior to presentation.

Computed tomography angiography (CTA) showed a total occlusion of the left common iliac artery (Figure 1). The case was discussed in a peripheral vascular disease multidisciplinary team (MDT) meeting and the patient elected to proceed with the endovascular option. Percutaneous iliac angioplasty and stenting were performed using a standard technique, with intravascular arterial pressures measured via an arterial line pressure catheter. Initial stent deployment was achieved using VBX Balloon Expandable Endoprostheses (W. L. Gore & Associates, Flagstaff, Arizona, USA): an 8 × 79 mm stent on the left and an 8 × 59 mm stent on the right. The right stent was subsequently post-dilated to 10 mm within the right common iliac artery (CIA).

Completion angiography showed a filling defect at the proximal aspect of the left stent, likely due to a fibrin cap at the apex of the chronic occlusion. To optimise flow, the iliac stents were extended bilaterally using additional VBX stents: 8 × 39 mm on the left and 9 × 39 mm on the right, inflated to 7 atmospheric pressure (ATM) to limit expansion to 8 mm. Final angiography showed satisfactory flow through both stents with preserved three-vessel runoff bilaterally (Figure 2). Post-procedural intravascular pressures were recorded as follows: left external iliac artery (EIA) 176/80 mmHg and right EIA 170/75 mmHg. The procedure went uneventfully, and the patient was discharged on dual antiplatelet therapy.

Figure 2 Bilateral common iliac angioplasty deployment of kissing common iliac artery (CIA) covered stents and extension with non-covered stents to both external iliac arteries with satisfactory completion angiography.



One week following the procedure the patient presented to the emergency department with mild left leg swelling and progressive unfamiliar back pain. CTA and duplex ultrasound confirmed stent patency and did not reveal any acute complications to account for the symptoms. However, fat stranding was noted around the left iliac stent and was interpreted as a potential early sign of peri-stent infection (Figure 3). A full peri-iliac stent infection work-up was initiated, including updated inflammatory markers, blood cultures, repeat CTA and a positron emission tomography-computed tomography (PET-CT) scan, which revealed occlusion of the left iliac stent.

The case was re-evaluated at the interventional radiology and vascular MDT, who initially agreed on a conservative management strategy. A repeat PET-CT scan was recommended if symptoms persisted. Blood cultures subsequently returned positive for *Staphylococcus epidermidis*, and the PET-CT scan demonstrated increased 18F-fluorodeoxyglucose (FDG) uptake around the left common iliac stent with a maximum standardised uptake value (SUVmax) of 10.6. Based on microbiology advice, intravenous antibiotic therapy was initiated.

After several weeks of treatment, repeat blood cultures turned negative, providing initial reassurance. However, the patient's back pain not only persisted but worsened, prompting a follow-up PET-

Figure 3 CT angiography and ultrasound scans showing fat standing around left common iliac artery stent which was interpreted as early signs of infection. Bottom right image: CT angiography showing left iliac stent occlusion.

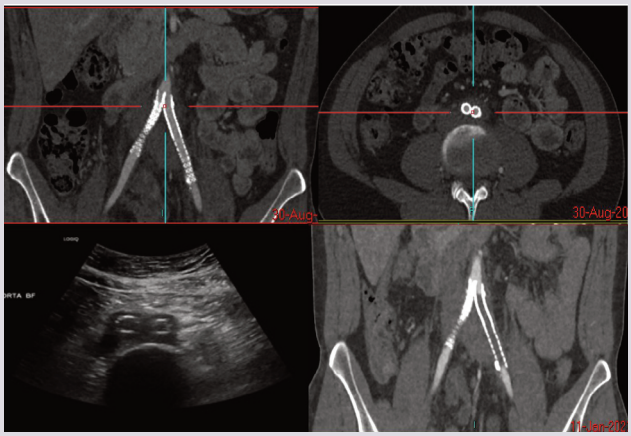
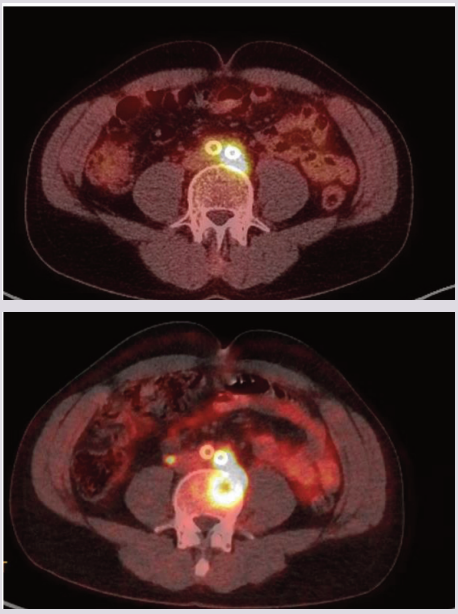


Figure 4 PET-CT scans performed at 3-month intervals with low-dose post-injection of 227 MBq 18F-fluorodeoxyglucose. TOF acquisition and Non Q Clear iteration reconstruction. Bottom image shows significant worsening in appearance of tracer avid soft tissue of the iliac stent centred towards the top. Soft tissue has increased in size and metabolic activity with new tracer avid erosions of L4 vertebra.



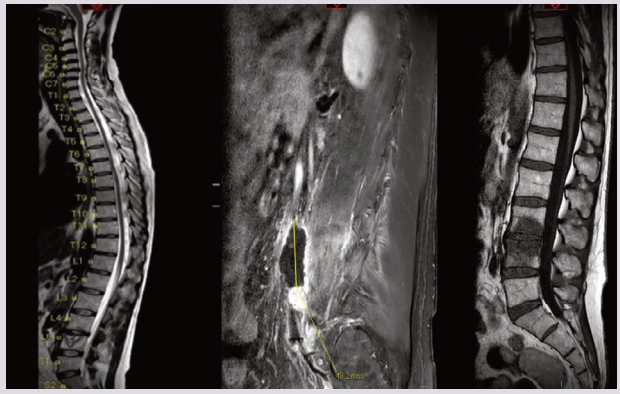
CT scan. This revealed further increased FDG uptake with new evidence of bony erosion involving the L4 vertebral body (SUVmax increased to 15.6) (Figure 4). These findings were re-discussed at the MDT meeting and the decision was made to explant the iliac stents and reconstruct the aortoiliac system.

The iliac stents were completely explanted and aortic reconstruction was performed using a bifurcated graft fashioned from a 10 × 16 cm bovine pericardial patch (XenoSure® bovine pericardial patch; LeMaitre Vascular, Burlington, Massachusetts, USA). The patch was divided into two strips, each fashioned into a tube graft using 5/0 Prolene sutures. All vascular anastomoses were constructed in an end-to-end fashion.

Intraoperative findings showed extensive inflammatory tissue enveloping the aortic bifurcation, with clear evidence of L4 vertebral body erosion. The left ureter was found adherent to the inflamed tissue and carefully dissected free. Specimens from the perispinal tissue, anterior wall of the left common iliac artery and the explanted stents were sent for histopathology and microbiological analysis. All samples grew *S. epidermidis*, consistent with prior blood culture results. Additionally, histological evaluation confirmed osteomyelitis involving the L4 and L5 vertebrae. The case was discussed with the infectious diseases team who recommended a prolonged course of antibiotics and interval follow-up with MRI of the lumbar spine.

Serial follow-up MRI scans of the lumbar spine initially demonstrated L4–L5 discitis and osteomyelitis, with marked destructive changes involving the L5 vertebral body and an associated prevertebral fluid collection 26 x 19 mm. The patient was treated with a prolonged course of intravenous antibiotics as per local microbiology recommendations, and subsequent imaging showed regressive radiological features with resolution of inflammatory changes and a significant reduction in the size of the prevertebral collection (Figure 5).

Figure 5 Serial MRI spine scans from left to right showing regressive radiological features of inflammation and pre-vertebral collection following explantation of the infected stents and extended course of antibiotics.



The patient was followed up for 6 months and showed good recovery, no symptoms or signs of infection and improved quality of life in terms of walking distance. However, the patient reported having retrograde ejaculation, which is one of the known complications of open aortic surgery, and has been referred to urology.

Discussion

The most common complications following endovascular treatment of AIOD are iatrogenic in nature, including vascular access site issues, arterial perforation, dissection and distal embolisation. Septic complications, on the other hand, are rare.[2] While the clinical course and management of prosthetic bypass graft infections are well documented, infections involving endovascular stents remain poorly characterised due to their rarity. Nonetheless, published reports suggest that stent infections carry a substantial burden of morbidity and mortality.[3] To our knowledge, this is the first documented infection of a VIABAHN VBX Balloon Expandable Endoprosthesis complicated by contiguous vertebral discitis. The unusually rapid onset – within one week of implantation – in an immunocompromised patient highlights the aggressive potential of this condition.

Although the overall incidence of stent graft infections is estimated to be less than 1%, when they do occur, these infections can result in catastrophic outcomes. Perioperative 30-day morbidity and mortality rates in the setting of stent graft infections have been

reported at approximately 35% and 11%, respectively.[4] Furthermore, within the first year postoperatively, the rates of graft-related complications and reinfection can exceed 10% and 5%, respectively. As such, prompt removal of the infected prosthesis and implementation of preventive measures are essential for improving outcomes. While most cases are caused by *Staphylococcus* species, infections due to *Salmonella* have been associated with particularly poor prognoses.[5]

Stent graft infections typically present with non-specific systemic symptoms such as fever, chills, malaise, fatigue and more localised signs including abdominal or back pain. CT imaging plays a central role, with typical findings including periaortic fluid collections, intraluminal or periaortic gas, soft tissue stranding and disruption of the aortic wall or aneurysm sac continuity.[6] Early imaging was decisive. PET-CT quantified metabolic activity with SUVmax values rising from 10.6 to 15.6, correlating with clinical deterioration and MRI evidence of a 26 × 19 mm prevertebral abscess. Such quantitative metrics are valuable for monitoring disease progression and guiding timing of surgery.

Smeds *et al* highlighted that the optimal management of infected stent grafts is explantation followed by reconstruction using autogenous tissue, owing to its superior resistance to reinfection.[4] When autologous reconstruction is not feasible, antibiotic-impregnated prosthetic grafts may serve as an acceptable alternative. Similarly, Chaufour *et al* demonstrated that complete explantation of the infected endograft remains the most effective strategy, often resulting in full resolution of infection and reducing the need for reintervention.[6] This evidence-based approach was adopted in our case, with favourable clinical and radiological outcomes following surgical explantation and antibiotic therapy.

Despite technological advancements, stent infections remain a rare but serious complication. The most commonly implicated pathogen is *Staphylococcus aureus*, with remote bacteraemia being a significant risk factor—often associated with indwelling intravascular catheters, restenosis angioplasty or intravenous therapies.[7] Animal models have demonstrated that balloon-expandable stents are particularly susceptible to infection when challenged intravenously with *S. aureus* within three weeks post-deployment.[8] In addition, *S. epidermidis* has been identified as a causative organism, likely introduced during the procedure itself.[9]

Infections involving iliac stents, though infrequent, represent serious complications with significant associated morbidity and mortality.[10] These infections have been documented in both bare metal and covered stents.[11] Contributing risk factors include poor aseptic technique, absence of perioperative antibiotic prophylaxis, and underlying patient comorbidities.[12] Accurate diagnosis often relies on a high index of suspicion, supported by imaging modalities such as CT or PET-CT scans.[10]

The VIABAHN VBX Balloon Expandable Stent has emerged as a reliable device in the treatment of iliac artery disease, demonstrating strong clinical outcomes. Studies comparing it with the Gore Iliac Branch Endoprosthesis indicate similar safety and effectiveness, with the VBX offering added benefits such as increased flexibility in branch configurations and a lower incidence of endoleaks. Its favourable properties – including high conformability – support its use in complex anatomy.[13] The VBX device consists of a stainless steel balloon-expandable frame covered by expanded polytetrafluoroethylene (ePTFE). While ePTFE provides excellent conformability and sealing properties, its microporous structure may allow bacterial adherence and biofilm formation when exposed to transient bacteraemia. The patient's prior lymphoma and chemotherapy likely resulted in prolonged B-cell depletion and impaired immune response, further predisposing to early infection.

KEY MESSAGES

- Rare ePTFE iliac stent infection progressed to vertebral discitis and osteomyelitis.
- PET-CT SUVmax 10.6 enabled early detection of peri-stent infection.
- *Staphylococcus epidermidis* was the causative organism of stents infection.
- Complete stent explantation and aortoiliac reconstruction were successfully performed.

Definitive management of iliac stent infections typically necessitates surgical removal of the infected prosthesis followed by arterial reconstruction, often employing autologous vein grafts.[14] Antibiotic therapy alone is rarely curative in these cases and is usually insufficient without surgical intervention.[11] Mortality rates associated with infected stent explantation have been reported to be between 12.5% and 32.5%, highlighting the potentially life-threatening nature of this condition.[10,11]

Conclusion

Endovascular therapy for AIOD is minimally invasive and has favourable short-term outcomes. Stent-related infections are an extremely rare but potentially devastating complication. This case highlights the diagnostic challenges and severe sequelae of iliac stent infection, including vertebral osteomyelitis and discitis, despite the use of modern covered balloon-expandable devices such as the VIABAHN VBX Endoprosthesis. Prompt diagnosis through multimodal imaging, microbiological confirmation and coordinated multidisciplinary decision-making were critical to achieving a favourable outcome in this patient. Ultimately, definitive management required surgical explantation, aortoiliac reconstruction, prolonged antimicrobial therapy and radiological surveillance. As the use of complex endovascular devices increases, clinicians must maintain a high index of suspicion for infection in the presence of unexplained systemic or localised symptoms post-intervention. This case underscores the importance of vigilance, early imaging and timely intervention to mitigate rare but life-threatening complications.

Conflict of Interest: None.

Funding: None.

Ethical approval and informed consent statements: All required ethical approval and informed consents were obtained for this case report.

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CASE REPORT

Surgical repair of a right proximal radial artery true aneurysm: case report and literature review

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Abstract

True radial artery aneurysms (RAAs) are exceptionally rare. We report a case of a 33-year-old man with an idiopathic fusiform true aneurysm of the proximal right radial artery, managed successfully via resection and reversed ipsilateral cephalic vein interposition bypass. Postoperative recovery was uneventful, with preserved distal perfusion and no complications at 6-month follow-up. This case underscores the importance of early surgical intervention for symptomatic RAAs and the efficacy of autologous vein grafts.

Introduction

Fewer than 24 true radial artery aneurysms (RAAs) have been reported since the first description by Thorrens *et al* in 1966.[1] While most radial artery aneurysms are pseudoaneurysms secondary to trauma or iatrogenic injury,[2] true aneurysms – characterised by dilation of all three arterial wall layers – are exceedingly rare, usually idiopathic but may be associated with connective tissue disorders.[3] Their diagnosis requires a threshold dilation of 1.5 times the normal radial artery diameter (2–3 mm).[3] This case underscores the diagnostic and surgical challenges of idiopathic RAAs, which lack established aetiological frameworks. Surgical repair is indicated for symptomatic aneurysms or those at risk of rupture/thromboembolism.[2,4] We report a case of idiopathic true RAA treated with resection and vein graft reconstruction, highlighting diagnostic and technical considerations.

Key words: idiopathic, interposition bypass graft, radial artery aneurysm, true aneurysm

Case presentation

A 33-year-old man presented with a tender pulsatile mass in the right proximal forearm, present for 3 months, accompanied by an intermittent cold sensation in the index and middle fingers. Comprehensive history revealed no antecedent trauma, previous vascular procedures or systemic symptoms suggestive of connective tissue disorders. Comorbidities included hypertension (controlled with amlodipine and candesartan). There was no family history of connective tissue disorders or risk factors for peripheral arterial disease.

Examination revealed a mildly tender pulsatile mass over the proximal radial artery without thrill or bruit on auscultation. Allen's test demonstrated an intact palmar arch. There were no signs of infection, thrombosis or distal ischaemia. A general examination was negative for pulsatile masses in the abdomen, groins or popliteal fossae. Neurological upper limb examination was normal.

Laboratory studies showed no evidence of systemic inflammation, metabolic derangement or autoimmune pathology. Vascular imaging with duplex ultrasound and contrast-enhanced CT angiography identified a 16.6 × 17.8 mm wide-necked aneurysm originating 3 cm distal to the origin of the radial artery, with preserved patency of the distal radial and ulnar arteries (Figure 1). Incidental imaging findings included a bovine aortic arch variant, a common anatomical variation present in 15–35% of the population, with no evidence of atherosclerotic disease in the upper extremity vasculature.[5]

Full written informed consent from the patient was obtained for publishing this article and accompanying images.

Figure 1 Computed tomographic angiography (CTA) of the right forearm demonstrating a saccular radial artery aneurysm.

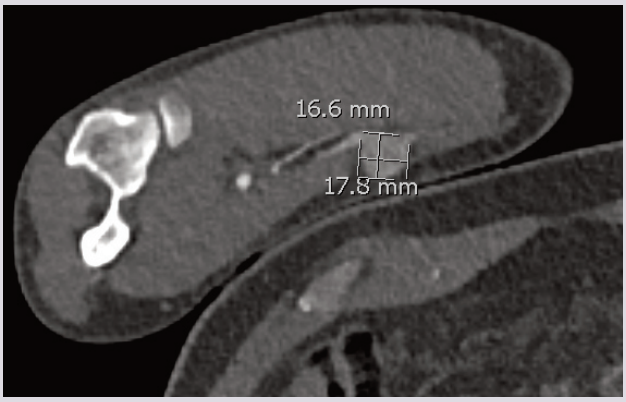


Figure 2 Intraoperative view of the isolated radial artery aneurysm prior to resection and venous interposition grafting.

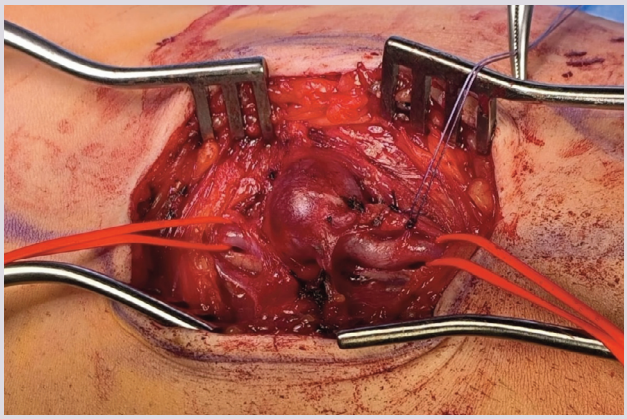
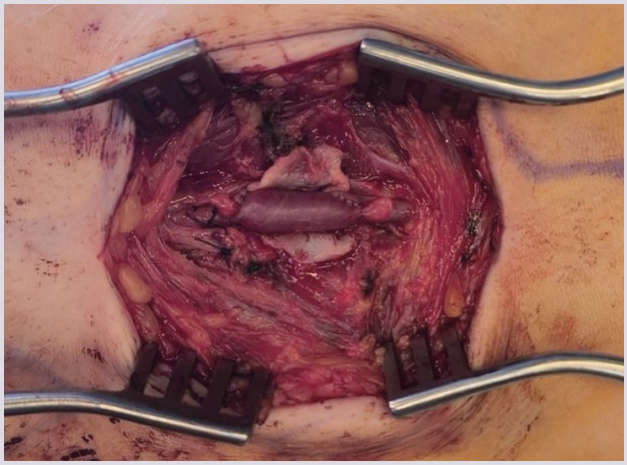


Figure 3 Intraoperative view following resection of the radial artery aneurysm and successful completion of the ipsilateral reversed cephalic vein interposition bypass.



Surgical management

Due to the associated tenderness of the aneurysm and potential risks of complications (eg, distal thromboembolism, compression of neighbouring structures, and lifetime rupture risk), after discussion at the multidisciplinary team meeting and with the patient he was scheduled for surgical repair of the right proximal RAA.[6] The surgical procedure was performed under general anaesthesia through a volar forearm approach. Meticulous dissection exposed the aneurysm while protecting the adjacent radial nerve (Figure 2). This incision was also used for the cephalic vein harvest which was later used for the bypass.

Proximal and distal control of the radial artery was achieved using bulldog clamps, and collaterals were controlled with 3/0 Vicryl slings. The aneurysmal segment was opened and arterial continuity was restored using an ipsilateral, reversed, short cephalic vein interposition bypass, anastomosed proximally and distally with 6/0 Prolene (Figure 3). Restoration of a palpable radial pulse confirmed graft patency and distal flow.

The decision to proceed with a cephalic venous interposition graft was made after considering several management options. Simple ligation of the radial artery was a feasible option, particularly given the patient's patent ulnar artery and a negative Allen's test confirming adequate collateral circulation. However, surgical revascularisation was selected to preserve a dual blood supply to the hand, an important consideration in a young patient. The cephalic vein was ultimately chosen as the conduit based on its optimal diameter match and the technical advantage of harvest without requiring an additional surgical incision.

Histopathological examination of the RAA wall confirmed the diagnosis of true aneurysm, demonstrating all three intact arterial wall layers with characteristic myxoid degeneration and fibrosis.

Outcome

The patient experienced an uncomplicated postoperative course and was discharged on the same day. At the 6-month follow-up appointment the patient was asymptomatic, with no sensory or motor deficits and a strong radial pulse and was subsequently discharged.

Discussion

This case of idiopathic true RAA contributes to the limited existing literature on this rare vascular condition. The clinical presentation – with a characteristic pulsatile mass and occasional distal coldness – aligns with previous case reports, although the absence of identifiable aetiology makes this case particularly noteworthy. The diagnostic approach, combining ultrasound and CT angiography, aligns with current best practices for vascular assessment.[7] Autologous vein grafts remain a preferred choice for arterial reconstruction due to their high patency rates and durable adaptive remodelling under arterial haemodynamic conditions.[8]

A RAA is characterised by a localised dilation exceeding 1.5 times the normal diameter of the vessel, which typically measures

KEY MESSAGES

- True RAAs are rare but clinically significant, requiring surgical intervention to prevent rupture or thromboembolism.
- Surgical reconstruction with an autologous cephalic vein graft is effective and preserves dual hand blood supply, especially in younger patients.
- Comprehensive diagnostic evaluation, including advanced imaging and systemic assessment, remains essential even in idiopathic cases.

2–3 mm in healthy individuals.[3] A true aneurysm involves all three layers of the arterial wall (intima, media and adventitia) and often results from structural weakening.[3] While most RAAs are pseudoaneurysms caused by trauma or iatrogenic injury (eg, arterial cannulation), rare cases are associated with connective tissue disorders, repetitive occupational trauma or idiopathic aetiologies.[9] RAAs typically present as a pulsatile mass and often require surgical intervention to mitigate potential complications including thromboembolic events or neurovascular compression.[6,9] Clinical manifestations may include pain, sensory disturbances (such as numbness or paraesthesia) or signs of distal thromboembolism.[4,9] While ultrasonography serves as the primary non-invasive diagnostic modality, advanced imaging techniques – including CT angiography, MR angiography and conventional angiography – provide comprehensive vascular assessment when indicated.[10]

The management of RAAs depends on the adequacy of the collateral circulation, assessed through diagnostic evaluations such as Allen's test or Doppler ultrasound. When the collateral circulation is sufficient, simple ligation and resection may be performed without reconstruction as the ulnar artery can maintain adequate hand perfusion. In cases where reconstruction is necessary, particularly in patients with inadequate collateral flow or high functional demand, surgical options include interposition vein grafting, typically using the great saphenous vein or a cephalic vein graft. Alternatively, primary end-to-end anastomosis may be considered if tension-free repair is feasible. Endovascular techniques such as coil embolisation or stent grafting represent less invasive options for selected patients, although their long-term efficacy in RAAs requires further study. The choice of treatment is individualised, balancing anatomical considerations, patient factors and functional outcomes.

Conclusion

This case reinforces key principles in managing true RAAs. It underscores the necessity of definitive vascular imaging for diagnosis and planning, the importance of multidisciplinary team discussion to tailor management and the obligation of comprehensive patient consultation regarding the risks and benefits of intervention. Finally, it highlights that, even in apparently idiopathic cases, a thorough evaluation for occult systemic disorders is still an essential component of care.

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Author contributions: RC: Writing – Original Draft, Writing – Review and Editing. HD: Writing – Review and Editing. MH: Conceptualisation, Writing – Review and Editing, Supervision.

Patient consent to publication: Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

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NEWS

Updates from the Vascular Societies

JVSGBI is owned by the Vascular Society for Great Britain and Ireland (VSGBI), for all affiliated societies and the wider vascular community. Here's the latest news from one of the societies.

British Society of Interventional Radiology (BSIR)

www.bsir.org
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BSIR held a very successful Annual Scientific Meeting in Liverpool in November 2025. This event saw a 17% increase in delegates, attending a full programme across 3 days of innovative IR research and clinical content. The feedback from delegates and industry partners has been overwhelmingly positive. Planning for 2026 is well underway, with the Scientific Programme Committee focussed on programme planning before the event opens for registration later in the year.

In the New Year, BSIR launched a number of new initiatives in January, including an open nomination process for the Society's Honorary Awards, applications for the inaugural BSIR Industry Scholarship programme and re-launched the Women in IR Ambassadors programme.

In February, BSIR announced the 2026 round for Research and Education Bursary applications (accessible to BSIR Members only), Applications are also now open for the Professor Anna-Maria Belli Grants, which support activities that promote Equality, Diversity and Inclusivity in Interventional Radiology, helping to inspire and welcome future colleagues from all backgrounds.

The BSIR event calendar is fully scheduled and kicks off in March with the BSIR Nurses & Radiographers Special Interest Committee CPD meeting, in Newcastle, in partnership with Terumo. This is followed swiftly by the second VITALS meeting (Vascular Innovation & Technology Advanced Learning Symposium) which will take place on 23rd-24th March at Sopwell House in St Albans.

Also coming up this year:

- BSIR Advanced Skills Course: 28th-29th April 2026, Harbour Hotel, Guildford.
- BSIR Basics Skills Course: 12th May, Clinical Science Building at UHCW, Coventry.
- Paeds IR Annual Meeting: 18th May, IET Austin Court, Birmingham.
- IOUK: 4-5th June, Crowne Plaza, Newcastle.
- Annual Scientific Meeting: 4-6th November, ICC Birmingham.

For more information about the Society and to register for any of these events, please visit www.bsir.org

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