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Ultrasound-guided infraclavicular axillary vein cannulation: a useful alternative to the internal jugular vein[†]

R. O'Leary, S. M. Ahmed, H. McLure, J. Oram, A. Mallick, B. Bhambra and A. R. Bodenham*

Department of Anaesthesia, Critical Care and Pain, Leeds Teaching Hospitals NHS Trust, Great George Street, Leeds LS1 3EX, UK

* Corresponding author. E-mail: andy.bodenham@leedsth.nhs.uk

Editor's key points

- Cannulation of the axillary vein (AxV) provides a potential alternative to subclavian vein cannulation that is more amenable to ultrasound (US) guidance.
- A retrospective analysis evaluated the success and complications reported in a large prospectively collected database of central vein catheterization at a large UK centre.
- US-guided internal jugular and AxV catheterization were both effective and relatively safe.

Background. Ultrasound (US) guidance reduces complications and increases accuracy during internal jugular vein (IJV) cannulation. The subclavian vein (SCV) is popular but is less amenable to US guidance. The axillary vein (AxV), a direct continuation of the SCV, is an alternative, but to date, experience with US is limited to small case series.

Methods. Retrospective procedural data were collected on 2586 sequential patients referred for insertion of tunnelled central venous access at a UK tertiary centre from 2004 to 2011.

Results. A total of 99.8% of patients tolerated the procedure with local anaesthesia $\pm$ sedation; six patients had general anaesthesia. Twenty-six (1%) patients had uncorrected coagulopathy or thrombocytopenia. A total of 2572 (99.5%) of patients were cannulated successfully: right AxV 1644 cases, left AxV 279, right IJV 547, left IJV 89, other techniques 13, and 14 (0.5%) cases failed. The initial site chosen was successful in 96%. In patients who previously underwent long-term cannulation, 93.3% of lines were sited easily. Forty-eight (1.9%) procedural complications occurred.

Conclusions. In this large analysis of US-guided central venous access in a complex patient group, the majority of patients were cannulated successfully and safely. The subset of patients undergoing AxV cannulation demonstrated a low rate of complications. The AxV route of access appears to be a safe and effective alternative to the IJV.

Keywords: equipment, ultrasound machines; vascular access; vein, axillary

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Ultrasound (US) guidance is now considered the gold standard technique for central venous catheter (CVC) insertion via the internal jugular vein (IJV).[1–3] The subclavian vein (SCV) is a useful alternative to the IJV and landmark techniques have been in practice for many years, despite the potential procedural complications. It is not easily amenable to US-guided access, however, because the clavicle obstructs views of the vessels. We have previously reported the anatomical background to US imaging of the axillary vein (AxV),[4] a direct continuation of, and alternative to, the SCV and our initial experience of US-guided AxV access.[5]

Since our initial study the resolution and availability of US guidance has improved, national systems to co-ordinate standards have evolved, and a consensus is emerging that patients benefit from US-guided placement of CVCs at many vascular sites in a variety of clinical settings.[6–11] Despite these advances, there are few large series which demonstrate the safety and advantages of US at sites other than the IJV. We now present a pragmatic, retrospective, evaluation of prospectively collected procedural data on a series of patients undergoing US-guided central venous access via the AxV and IJV routes. We concentrate our analysis on the infraclavicular route of access to the AxV.

Methods

Patient selection and data collection

All procedures were performed under the auspices of a large UK tertiary centre at one of five hospitals in Leeds (St James's University Hospital, Leeds General Infirmary, The Nuffield Leeds, Spire Hospital, and Cookridge Hospital) between June 2004 and August 2011. The majority of patients were undergoing treatment for solid and haematological malignancies, chronic immunosuppressive conditions, or chronic nutritional disorders. Patients varied from having essentially normal anatomy to more complicated pathologies due to

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the presence of obstructing tumours, coagulopathy, or acquired central vein stenosis. The local research ethics committee determined that this study was a service evaluation not requiring formal research ethics approval or patient consent over that routinely obtained for the procedure.

Patients were referred by completion of a faxed request form which outlined basic patient details and, if necessary, telephone screened before booking. On the day of operation, a bedside assessment was made by the operating clinician to evaluate the type and requirements of the catheter, the presence of anatomical and pathological conditions influencing the choice of site, previous long-term central venous access, and any other potential difficulties. Each procedure was performed by a consultant anaesthetist, a consultant supervising a specialist in training, or a nurse specialist in vascular access. All cases were managed during regular elective theatre sessions with routine availability of real-time US and X-ray imaging.

Data were collected on each patient immediately after the procedure using a carbon-copy paper form. Patient demographic information, clinical details, site, technique, attempts, and complications were recorded. The original of this form was placed in the patient records as an operation note and the copy kept for this audit and anonymized before analysis. When reviewed, complete data were recorded for all patients who underwent a cannulation procedure.

Anaesthesia and sedation

All patients were monitored with standard theatre equipment supervised by a nurse or operating department practitioner. The operating clinician was assisted by a scrubbed theatre nurse. Unless contraindicated, patients were offered i.v. midazolam and fentanyl sedation with 3 litre min^{-1} oxygen via a facemask. General anaesthesia, administered by a separate anaesthetist, was reserved for patients with specific needs. Local infiltration anaesthesia with lidocaine 1% plus 1/200 000 epinephrine was administered through a 23 G needle and 22 G 3.3 in spinal needle.

Technique

We described the basic principles of our technique elsewhere,[5] [12] but in these earlier reports, US was used as a rescue technique after failure of landmark guidance. Our US technique differs from historical landmark approaches to the AxV which never achieved widespread acceptance arguably because they are associated with an unsatisfactory incidence of complications.[13] [14]

Patients were positioned in a neutral supine position on an operating table ~15° head-down. No additional manipulations such as a Valsava manoeuvre, traction on arms, extreme head rotation, or digital pressure on the neck were used routinely.

Under full operating aseptic conditions, the skin was prepared with 2% chlorhexidine in 70% isopropyl alcohol. The operating area was isolated with wide surgical drapes to allow simultaneous access to the IJV and AxV sites (Fig. 1A). US imaging was performed initially in the case series with a SonoSite iLook™ device with a 10–5 MHz probe and subsequently with a SonoSite S-Nerve™ device with a HFL38/13–6 MHz probe (SonoSite Ltd, Biggleswade, UK). The vein and the axillary artery (AxA) were first imaged in short axis to determine the depth from the skin (Fig. 2A) and the probe was then rotated to perform a long-axis examination to identify other structures, such as
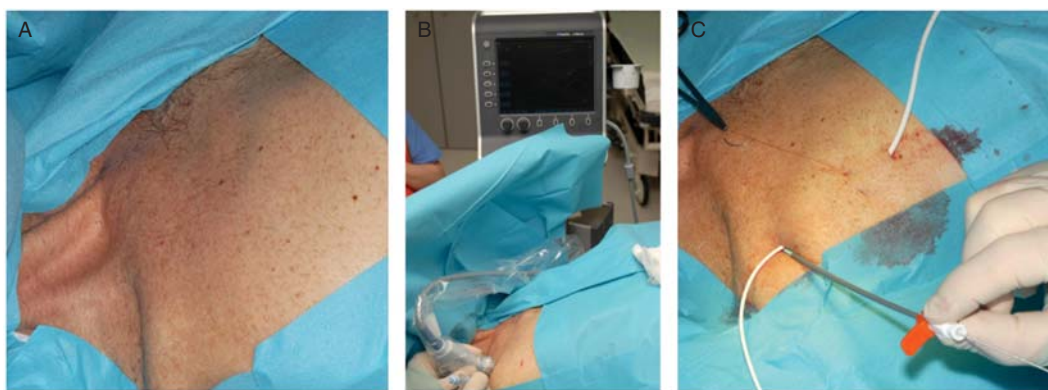
Fig 1 Insertion sequence for AxV cannulation. (A) The patient is positioned as described in the Methods section, prepared and draped to allow access to both the infraclavicular and internal jugular sites without moving drapes. (B) The US probe is positioned at a mid-clavicular position with the screen opposite to the operator. Once the axillary vein, axillary artery with its branches, the first and second ribs, and the pleura are identified the optimal site for vein puncture is chosen. The needle is introduced at a steep angle aiming away from the dome of the pleura and, in this example, is attached to a self-filling negative pressure balloon device (Raulerson Bulb, Medical Components, Inc., Harleysville, PA, USA). (C) After successful vein puncture, the guidewire has been inserted and splitting sheath is ready to be introduced. The Hickman line has been tunnelled up to the venous access incision and cut to length before insertion. The suture shown was inserted around the tunnelling rod then later tied off and buried, and functions to prevent early cuff movement.
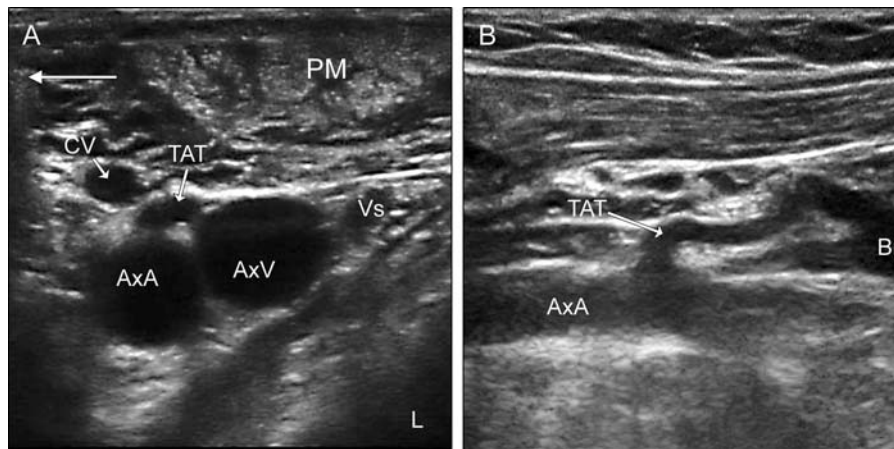
Fig 2 US anatomy of the infraclavicular region: (A) cross-sectional US image of the right infraclavicular area shows the right axillary vein (AxV) in the centre of the screen, the cephalic vein (CV), and the axillary artery (AxA). The branch of the AxA, the thoracoacromial trunk (TAT), crosses the vein. A further vessel (Vs) seen is a branch of the TAT; L, lung; PM, pectoralis minor; arrow indicates the direction of the head. (B) Image demonstrating oblique long-axis views of the AxA, TAT, and the AxV. The TAT branches anteriorly from the mid-section of the AxA and usually forms into four tortuous branches (Br) (pectoral, acromial, clavicular, and deltoid). In this image, the TAT, or one of its branches, can be seen to curl inferiorly to overlie the AxV, a common finding.

branches of the axillary artery, which can cross the AxV (Fig. 2B) and the optimum site for venous puncture was determined. The probe was then returned to the short axis and the introducer needle was advanced out of plane at a steep angle towards the vein until the tip was seen to indent the vein wall. Vein puncture was identified by free aspiration of non-pulsatile blood. After insertion through the introducer needle, the guidewire was seen by fluoroscopy to ensure that the tip was in a satisfactory position in the superior vena cava or right atrium. The distance from the initial puncture site to the desired tip position was measured from markings on the guidewire.

The catheter and cuff were tunnelled subcutaneously from an exit site on the chest wall to the vein puncture site and a dilator and splitting sheath were passed over the guidewire into the vein (Fig. 1c). The catheter was then cut to length, and inserted through the splitting sheath and its position checked and adjusted using the image intensifier. The length of the catheter in the vein could be changed by moving the anchoring cuff along its subcutaneous tract. Catheters used included 6.6 Fr Broviac type cuffed silicon single-lumen catheter, 9.5 Fr Hickman type dual-lumen catheter, 6.6 Fr implanted port (Vygon UK Ltd, Cirencester, UK), and various dialysis catheters. The standard 18 G introducer needle and guidewire provided by the manufacturers with the relevant catheter were initially used in all cases. After insertion of the catheter, line position was checked routinely. Contrast (Omnipaque™, GE Healthcare, Amersham, Buckinghamshire, UK) was used to enhance visibility of the catheter if needed and contrast injected through the catheter to ensure SVC position if concerns arose in more challenging cases. When this was required, it was recorded on the audit form. Long, coated Terumo Radiofocus™ Nitiniol

guidewires (Terumo, Ann Arbor, MI, USA) passed through an introducer cannula were found to be very useful in the presence of complicated, distorted, or stenotic vascular anatomy. In addition, they could be passed through the final catheter to aid central passage.

Results

All 3335 patients accepted for scheduling are included for completeness: 2586 underwent attempted central venous cannulation; 721 had catheters removed; five patients were referred for replacement but found to have functioning devices; 20 patients had a peripherally inserted central catheter (PICC) placed; and three patients had a CVC inserted using land mark techniques without attempting US guidance (Fig. 3). The mean age was 60, median 62, range 6–93 yr (three children were accommodated on a predominantly adult list), male 53.5% and female 46.5%. Six out of 2586 (0.2%) patients were given a general anaesthetic. All of the remainder had local anaesthesia and 955 of 2586 (36.9%) patients were sedated. Twenty-six (1%) patients had uncorrected therapeutic anti-coagulation or were thrombo-cytopenic (platelet count $< 50\,000\ \mu l^{-1}$); pre-procedural coagulopathy was usually corrected before booking. The range of underlying diagnoses was wide; the majority of patients required vascular access for chemotherapy or parenteral nutrition, and smaller numbers were referred for dialysis/apheresis or long-term antibiotic requirements.

US-guided central venous access was attempted in 2586 patients and was successful in 2572 (99.5%) patients. The AxV was used in 1923 cases and the IJV in 636 cases. In 13 cases, a catheter was sited by "rescue" landmark techniques after failed US-guided access, typically via the
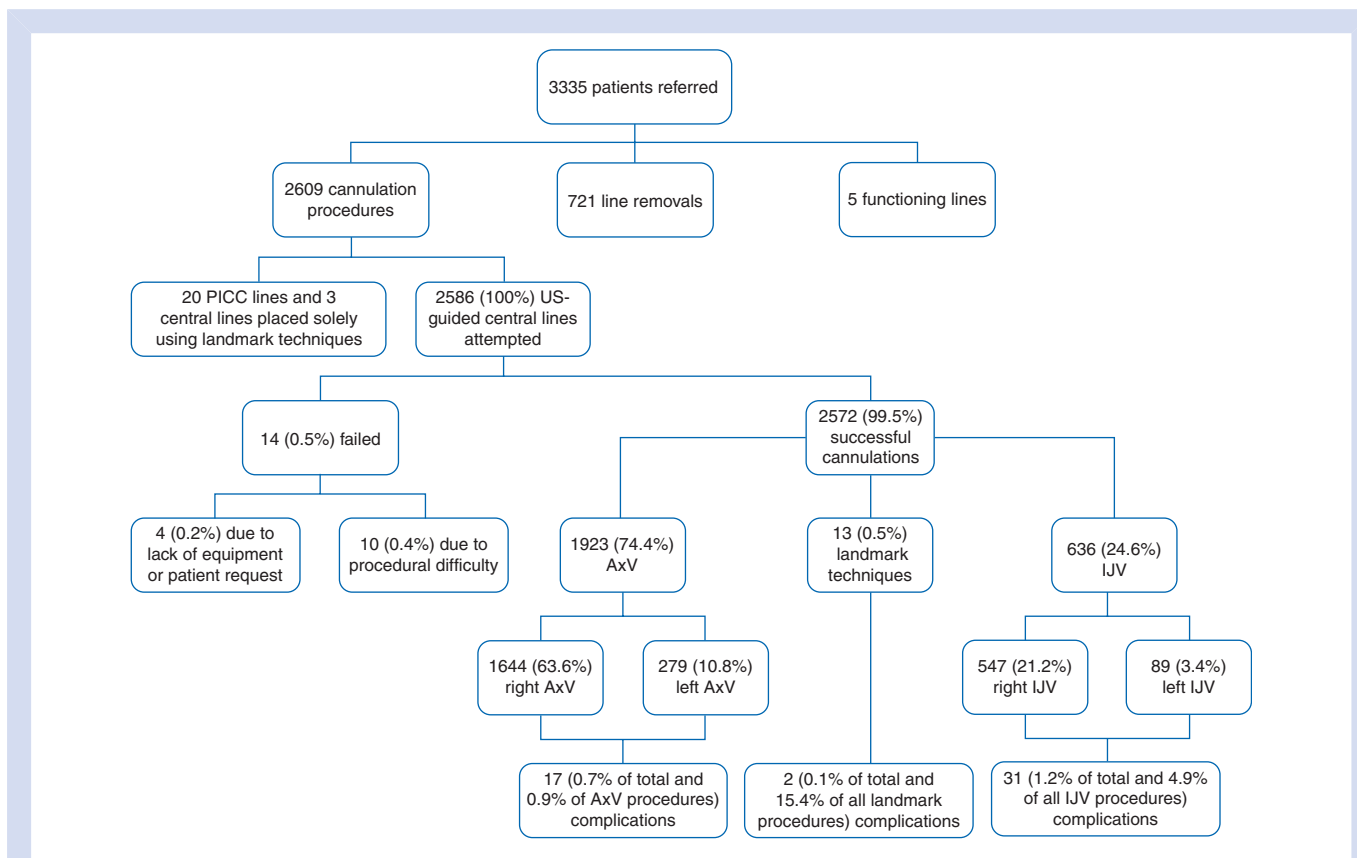
Fig 3 Consort-style diagram: the outcomes of all patients accepted for central venous access or line removal (3335 patients). The 2586 patients who underwent attempted US-guided central venous access are analysed in this study. PICC, peripherally inserted central catheter; US, ultrasound; AxV, axillary vein; IJV, internal jugular vein.

subclavian route after US visualization or cannulation of the AxV proved difficult.

The indications for site selection were not routinely recorded. Right-sided placements are generally preferred due to easier central tip positioning. The right AxV was cannulated in 1644 (63.6%), the left AxV in 279 (10.8%), the right IJV in 547 (21.2%), and the left IJV in 89 (3.4%). The use of contrast venography to aid with challenging vascular anatomy or difficulties in visualizing narrow-gauge catheters was recorded in 16.0% of cases, with the proportion similar between sites.

The central venous site initially chosen could not be cannulated in 102 of 2586 procedures (3.9%). Eighty-eight were successfully cannulated at an alternative central site, usually within one or two subsequent attempts (Table 1). Cannulation failed completely in 14 (0.5%) patients: 10 (0.4%) could not be completed due to blocked or tortuous central veins, two due to faulty or absent equipment, and two where the patient could not tolerate the procedure. Four hundred and fifteen patients (16.0%) had had a previous long-term central venous access device before the insertion of the catheter in this study. Within this group, 322 required one needle pass attempt, 65 required two attempts, and 28 required three or more attempts.

Complications were recorded in 48 (1.9%) cases. There were 31 complications related to haemorrhage, arterial

Table 1 Site conversions: list of cases where more than one site was required to gain successful access. Within this group, there will be patients who had more than one site in the conversion sequence, but only the starting and final successful site are recorded here

Conversion	Cases
Axillary to internal jugular	55
Axillary to landmark subclavian	6
Axillary to external jugular	1
Axillary to contralateral axillary	2
Internal jugular to axillary	14
Internal jugular to contralateral internal jugular	4
Internal jugular to landmark subclavian	6
Total	88

puncture, or bleeding at access sites (Table 2). Arterial puncture occurred in 19 cases (with two haematomas recorded); of which, 11 were at the IJV site and eight at the AxV site. In one case, a 6.6 Fr sheath was passed into the axillary artery and removed immediately. The superior vena cava was perforated once with a guidewire after AxV cannulation which was identified with contrast after passage of a 16 G catheter, no problems followed guidewire removal. There were 10

Table 2 Haemorrhagic complications and vessel injuries

Procedure	Cases
Arterial puncture at the internal jugular site	11
Subsequent haematomas	2
Arterial dilatation or cannulation	0
Arterial puncture at axillary site	8
Subsequent haematomas	0
Arterial dilatation or cannulation	1
Arterial puncture at the subclavian site	1
Superior vena cava perforation with contrast leak during AxV cannulation	1
Minor bleeding at skin surface	10
Total	31

Table 3 Non-bleeding complications

Procedure	Cases (*n*)
Arrhythmia requiring treatment	4
Angina	1
Early pneumothorax	1
Late pneumothorax (AxV)	2
Aspiration of pre-existing pleural effusion (AxV)	1
Agitation or difficulty titrating sedation	4
Acute psychosis requiring psychiatric intervention	1
Paraesthesia during procedure	1
Significant pain during procedure and then abandoned	1
Allergic reaction to latex	1
Total	17

further cases of minor bleeding recorded at all of the cannulation sites. None of the bleeding complications required blood product transfusion or operative intervention.

Seventeen patients developed other complications (Table 3): four (all AxV) patients developed short-term arrhythmias which resolved without cardioversion. One pneumothorax was evident during cannulation, two cases presented later. A chest drain was required in one of these cases and the others were managed conservatively. In one further case (AxV), a pre-existing pleural collection was cannulated and then partially aspirated without further problems.

Less specific minor technical problems were recorded in ~20% of cases. Typically, these were difficulties in passing or positioning guidewires, introducers, or catheters. The incidence of small technical difficulties is likely to be higher, since different operators will have varying thresholds for recording awkward cases.

After the use of the image intensifier, catheter position required manipulation in 728 (28.2%) patients; of which, 348 had undergone right AxV cannulation and 44 left AxV.

The mean length of the catheter inserted through the various sites was as follows: right AxV was 19.4 cm, left AxV 23.0 cm, right IJV 16.5 cm, left IJV 19.3 cm.

Discussion

This is a retrospective analysis of prospectively collected clinical data from a large cohort of unselected patients with significant co-morbidities undergoing US-guided central venous cannulation in a single large UK tertiary health centre. This is one of the most extensive series of its kind, and the subset of patients who received AxV lines is the largest reported. We demonstrate that the AxV is a safe and effective alternative to the IJV route while offering advantages over landmark CVC access and similar US-guided techniques.

Iatrogenic injury associated with CVCs persists, despite improvements in insertion techniques and better surveillance of catheter-related sepsis. When used at the IJV site, US reduces complications, number of attempts, and time to successful cannulation.[6 7 15] The use of US is recommended by the United Kingdom National Institute of Clinical Excellence[16] and the United States Centre for Disease Control (CDC)[17] and other consensus guidelines from a variety of clinical specialities.[1 3 18 19] Furthermore, evidence is accumulating that confirms the utility of US at other vascular sites, such as a supraclavicular approach to the IJV/SCV in adults[10] and children,[8] the femoral vein,[9] and the saphenous vein in children.[11]

Currently, evidence to mandate the use of US at sites other than at the IJV is incomplete. This is particularly pertinent at the SCV which offers advantages over the IJV and femoral sites and is suggested by the CDC as the optimum site for CVC access,[17] a position supported by a recent meta-analysis.[20] In contrast, and as a result of the relative lack of evidence, the ASA does not recommend the use of US for this route.[19]

There is a range of US-guided techniques described that all, despite differences in nomenclature, involve puncture of the SCV, root of the IJV, or AxV in close proximity. For example, an infraclavicular parasternal approach to the SCV[21] (arguably the proximal AxV)[22] showed superiority of US over a landmark technique. This method, while effective, was described by the authors as being technically difficult. Alternatively, a technique where an infraclavicular needle was seen in plane by a supraclavicular probe showed improvements in safety over landmark techniques.[23]

Our method differs from these in that it uses an infraclavicular approach to puncture the AxV in its mid-section, therefore avoiding difficulties in trying to visualize vessels in close proximity to the clavicle and sternum (Figs 1 and 2). This study sought to determine whether the AxV was a consistently reliable site for US-guided access and whether it offered an alternative to landmark techniques to cannulate the SCV. We now confirm that it is efficacious in the majority of a heterogeneous mix of patients, 99.5% of the 1923 attempts at the AxV were successful, 94% on the first attempt. Also, the incidence of complications in this study

is consistent with rates in the US arm of studies that have compared US with landmark techniques.[6 10 15 21 23]

Inevitably, the case series did exhibit some peri-procedural complications. This is an interesting and challenging part of our audit process. The term 'peri-procedural complication' was not explicitly defined and it was left to the operator to record any untoward or unexpected event. Major haemorrhage, arrhythmia leading to haemodynamic instability, and pneumothorax would clearly be recorded. The less worrisome complications may not have been so assiduously documented.

There were 48 (1.9%) complications, 17 (0.7%) out of 1923 AxV cases and 31 (4.9%) out of 636 IJV cases. A superficial examination suggests that the rate of complications is lower in the AxV group compared with the IJV group (χ^2 $P<0.001$). However, this observational study does not lend itself to robust statistical analysis, not least because the IJV group would be likely to include patients considered more technically challenging or those who had failed cannulation of the AxV.

There were 19 cases of arterial puncture, again proportionally more in the IJV group where there were 11 instances. None of the these injuries required follow-up, transfusion, or operative repair. The rate of 0.4% in the AxV group is very similar to that reported by Cavanna and colleagues[10] (0.3%) in their supraclavicular IJV technique and Fragou and colleagues[21] (0.5%) using their parasternal SCV approach. These data may suggest that the AxV is associated with a lower rate of arterial punctures. We cannot be certain that we have recorded all of the instances of arterial injury in the AxV group, the depth of the AxV and its dense surrounding connective tissue means that smaller haematomas may have gone unnoticed. Moreover, the complex anatomy of the axillary artery and the thoracoacromial arterial trunk may mean that arterial punctures that go unrecognized during successful venous cannulation, a phenomenon reported during pacemaker placement.[24]

Pneumothorax is a recognized and worrying complication of landmark SCV cannulation. We observed one case where a pneumothorax was visible on the immediate post-procedural chest radiograph and one case where a pleural collection was aspirated and which the operator felt would have resulted in a pneumothorax had the fluid not been present. There were two cases where pneumothoraces were detected in other clinical areas after discharge from the postoperative recovery area. All four of these cases occurred during AxV cannulation, giving an incidence of pleura/lung injury of 0.2% which compares with 0% described using similar techniques.[10 21 23]

The other complications were a disparate mix of untoward events, associated with any invasive procedure in a complex mix of patients. We are reassured by the lack of brachial plexus problems which reflects the orientation of the plexus at the mid-point of the AxV where the nerves are more closely applied to the artery.

A retrospective, single-centre study such as this has inherent shortcomings, but the most significant limitation is our lack of data on long-term complications including catheter sepsis and thrombosis. In part, this is a consequence of increasing numbers of patients referred from peripheral hospitals. The care of these patients and their follow-up remain at the referring centre, hospice, or at home. Aspects of our data do reassure us, for example, the high incidence of straightforward cannulations that established access on the first attempt suggests that many of the cases were completed with very few skin punctures. US is associated with reduced catheter-related blood stream infections[6] and reduces the number of needle passes. It seems plausible that the number of skin punctures and the length of time to successful catheterization correlates with the translocated bacterial burden. More importantly, we expect that we would have received feedback from the referring clinicians if our complication rate was anything other than optimal.

It is essential to consider how well our technique transfers to critical care, emergency, and theatre areas. Our complex group of patients is large, heterogeneous, and represents a thorough examination of the technique. Many of the patients had pathology that would cause difficulties with cannulation and most were awake and would have co-operated poorly with clumsy and repeated procedures. We were confident about extending this technique outside of this patient group and currently successfully use US-guided AxV cannulation in patients in intensive care units, and acute and elective theatres.

This is the largest study of US-guided AxV cannulation, albeit with the shortcomings associated with service evaluations, and provides compelling evidence that the AxV offers an effective alternative to US-guided IJV and SCV cannulation. However, the AxV approach is technically more difficult than the IJV approach; the AxV is deeper, and surrounded by the axillary artery, the brachial plexus, and the chest wall and pleura. Once mastered, however, this is a safe, useful, and reliable technique for central venous access.

Declaration of interest

A.R.B. is a member of the Editorial Boards of *British Journal of Anaesthesia* and *Journal of the Intensive Care Society*.

References

1 Troianon CA, Hartmann GS, Glas KE, *et al.* Guidelines for performing ultrasound guided vascular cannulation: recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr* 2011; **24**: 1291–318

2 Fearnley RA, Bell MD, Bodenham AR. Status of national guidelines in dictating individual clinical practice and defining negligence. *Br J Anaesth* 2012; **108**: 557–61

3 Lamperti M, Bodenham AR, Pittiruti M, *et al.* International evidence-based recommendations on ultrasound-guided vascular access. *Intensive Care Med* 2012; **38**: 1105–17

4 Galloway S, Bodenham A. Ultrasound imaging of the axillary vein—anatomical basis for central venous access. *Br J Anaesth* 2003; **90**: 589–95

5 Sharma A, Bodenham A, Mallick A. Ultrasound-guided infraclavi-cular axillary vein cannulation for central venous access. *Br J Anaesth* 2004; **93**: 188–92

6 Karakitsos D, Labropoulos N, De Groot E. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. *Crit Care* 2006; **10**: R162

7 Leung J, Duffy M, Finckh A. Real-time ultrasonographically-guided internal jugular vein catheterization in the emergency department increases success rates and reduces complications: a randomized, prospective study. *Ann Emerg Med* 2006; **48**: 540–7

8 Pirotte T, Veyckemans F. Ultrasound-guided subclavian vein can-nulation in infants and children: a novel approach. *Br J Anaesth* 2007; **98**: 509–14

9 Aouad MT, Kanazi GE, Abdallah FW, *et al*. Femoral vein cannulation performed by residents: a comparison between ultrasound-guided and landmark technique in infants and children undergoing cardiac surgery. *Anesth Analg* 2010; **111**: 724–8

10 Cavanna L, Civardi G, Vallisa D, *et al*. Ultrasound-guided central venous catheterization in cancer patients improves the success rate of cannulation and reduces mechanical complications: a prospective observational study of 1978 consecutive catheteriza-tions. *World J Surg Oncol* 2010; **8**: 91

11 Triffterer L, Marhofer P, Willschke H, *et al*. Ultrasound-guided can-nulation of the great saphenous vein at the ankle in infants. *Br J Anaesth* 2012; **108**: 290–4

12 Hatfield A, Bodenham A. Portable ultrasound for difficult central venous access. *Br J Anaesth* 1999; **82**: 822–6

13 Nickalls RW. A new percutaneous infraclavicular approach to the axillary vein. *Anaesthesia* 1987; **42**: 151–4

14 Taylor BL, Yellowlees I. Central venous cannulation using the infraclavicular axillary vein. *Anesthiology* 1990; **72**: 55–8

15 Hind D, Calvert N, McWilliams R, *et al*. Ultrasonic locating devices for central venous cannulation: meta-analysis. *Br Med J* 2003; **327**: 361

16 *NICE Technology Appraisal Guidance No 49: Guidance on the Use of Ultrasound Locating Devices for Placing Central Venous Cathe-ters*. London: National Institute of Clinical Excellence, 2002. Avail-able from http://guidance.nice.org.uk/TA49 (accessed 5 April 2012)

17 O'Grady NP, Alexander M, Burns LA, *et al*. Guidelines for the pre-vention of intravascular catheter-related infections. *Clin Infect Dis* 2011; **52**: e162–93

18 Bishop L, Dougherty L, Bodenham A, *et al*. Guidelines on the in-sertion and management of central venous access devices in adult. *Int J Lab Hematol* 2007; **29**: 261–78

19 American Society of Anesthesiologists Task Force on Central Venous Access. Practice guidelines for central venous access. *Anesthesiology* 2012; **116**: 539–73

20 Parienti J-J, du Cheyron D, Timsit J-F, *et al*. Meta-analysis of sub-clavian insertion and nontunneled central venous catheter-associated infection risk reduction in critically ill adults. *Crit Care Med* 2012; **40**: 1627–34

21 Fragou M, Gravvanis A, Dimitriou V, *et al*. Real-time ultrasound-guided subclavian vein cannulation versus the landmark method in critical care patients: a prospective randomized study. *Crit Care Med* 2011; **39**: 1607–12

22 Bodenham AR. Ultrasound-guided subclavian vein catheteriza-tion: beyond just the jugular vein. *Crit Care Med* 2011; **39**: 1819–20

23 Milone M, Di Minno G, Di Minno M, *et al*. The real effectiveness of ultrasound guidance in subclavian venous access. *Ann Ital Chir* 2010; **81**: 331–4

24 Smith JA, Affolter JT, Patel JC, Broadhurst P. Arterial trauma during ultrasound-guided axillary vein puncture for endocardial lead placement. *Europace* 2009; **11**: 660–1