TECHNIQUES, ADVANTAGES AND PITFALLS OF ULTRASOUND-GUIDED INTERNAL JUGULAR CANNULATION: A QUALITATIVE STUDY

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ABSTRACT

Background: National guidelines advocating ultrasound-guidance of internal jugular venous cannulation were introduced in the United Kingdom in 2002, followed by international guidelines a decade later. However the benefits of ultrasound-guidance do not appear to have universally translated into clinical practice. This study therefore aimed to investigate the effect of ultrasound on the practice of internal jugular vein cannulation.

Methods: We conducted an ethnographic study incorporating observations, interviews and focus groups in two hospitals in the North of England over a four-month period.

Results: Twenty-seven clinical observations, ten interviews and three focus groups were conducted. In 25 clinical episodes ultrasound-guidance was used. Four distinct needling techniques were observed which we have classified in terms of needle angulation as the *traditional landmark technique*, the *ultrasound-guided traditional approach, ultrasound-guided medial angulation,* and the *ultrasound-guided steep approach.* The latter two techniques represent a departure from conventional practice and appear to have developed alongside ultrasound-guidance. Though no serious complications were observed, there appears to be enhanced potential for them to

occur with medial angulation and the steep approach. Participants described a loss of anatomical knowledge and a 'false sense of security' associated with the adoption of ultrasound-guidance, which may account for the emergence of new, potentially riskier needling techniques.

Conclusion: The introduction of safe technologies may lead to unintended consequences, and clinicians should attempt to recognise and mitigate them when they occur. Education to increase awareness of the pitfalls of ultrasound-guidance is recommended.

KEY WORDS (MeSH): ultrasonography, interventional; catheterization, central venous; patient safety; social sciences;

BACKGROUND

Percutaneous cannulation of the internal jugular vein (IJV) using an approach based on anatomical landmarks was first described in the 1960's.[1,2] In the decades that followed, a number of variations on the technique were developed which shared the common principles of a shallow angle of needle insertion in a trajectory which does not transect the carotid artery.[3,4] Despite these anatomical principles, landmark-based cannulation of the IJV is associated with a number of potentially serious procedural complications.[5,6] In addition to this, procedural failure results in delayed administration of therapy. In an attempt to address these issues, ultrasound-guidance was pioneered by Yonei in 1986, who reported a case series of 160 IJV cannulations without complication.[7] This innovation was followed by numerous randomised controlled trials comparing ultrasound-guidance with landmark-based techniques.[8-14] These trials universally favoured the safety and efficacy of the new technique, and prompted the National Institute for Clinical Excellence (NICE) to issue guidelines in 2002 advising the use of ultrasound to guide all elective IJV central line placements.[15,16] A decade later, international evidence-based recommendations were published, advocating the routine use of ultrasound for central venous access, regardless of anatomical site or urgency.[17]

Despite the unequivocal recommendations of guideline authors, the transition to ultrasound-guidance has been incomplete: the most recent national survey of central venous cannulation practice in the UK, conducted in 2006, suggests that ultrasound-guidance is the 'first choice technique' for only about one-third of senior anaesthetists, with the largest proportion preferring to use anatomical landmarks.[18,19] Furthermore, the degree to which the reduction in complications obtained using ultrasound-guidance in the research setting translates to clinical practice is unclear,

with some authors reporting an increase in complications following its introduction.[20] Implicit within such counter-intuitive findings is that there are various ways to use ultrasound in the insertion of IJV cannulae, and that some methods may be less safe than others, or less safe than not using ultrasound at all. Variation in ultrasound-guided IJV cannulation practice can be found in the existing literature; for example Yonei initially described an in-plane approach whereas the trials on which the NICE guideline was based all adopted an out-of-plane technique.[7-14] Beyond this however, the techniques employed in each trial were not fully described, with information such as the anatomical site and direction of needle insertion omitted. Though an exhaustive description of any practical technique is unattainable due to the presence of a tacit element,[21] the dearth of description in the existing literature leaves the clinician with little direction as to how to best use ultrasound-guidance, and creates the conditions for variation in practice to occur.

In order to explore the 'real world' techniques used for ultrasound-guidance of IJV cannulation in clinical practice, we conducted an ethnographic study in two teaching hospitals in the North of England between July and October 2013.

METHODS

Approvals from the research and development departments of the participating hospitals and the Lancaster University Faculty of Health and Medicine Ethics Committee were obtained. Members of the hospitals' anaesthetic and intensive care departments were briefed in writing and verbally. Written informed consent was obtained from all of the clinicians who participated, and research was conducted according to Good Clinical Practice guidelines.

Adopting an ethnographic approach allows the practice within a particular setting to be explored. It makes use of systematic direct observation, informal discussion, and secondary techniques such as interviews to allow the researcher to illuminate a particular phenomenon, in this case the techniques used for ultrasound-guided cannulation of the IJV.[22,23]

The settings within hospitals were stratified: hospital 1 was divided into theatres and intensive care, and hospital 2 into theatres, intensive care, and cardiothoracics. Data collection in each of these settings commenced with semi-structured interviews with the consultants responsible for management of the department (e.g. clinical director) and for the training of junior staff (e.g. college tutor). The purpose of these interviews was to provide context for the study. This was followed by observation of clinical episodes in which IJV catheterisations were attempted. The clinical episodes were purposively sampled using a maximum variation strategy: aiming to observe the widest possible variety of clinical settings, grades of anaesthetist, times of day and degrees of clinical urgency. The study was concluded with semi-structured focus group discussions to which all study participants were invited. All observations and interviews were undertaken by the same researcher (CS), who is an anaesthetic registrar familiar with the procedure and settings under study.

Data was recorded by way of audio recording (interviews and focus groups) and field notes (interviews, focus groups and observations). These notes and recordings were transcribed at the earliest convenience. Names of individuals and institutions were replaced with anonymised identifiers (e.g. ‘consultant 1 (C1)’, ‘trainee 2 (T2)’) and original recordings and notes were confidentially destroyed. The anonymised transcripts were then imported into Atlas.ti version 7 (Atlas.ti Scientific Software Development GmbH, Berlin) for coding and analysis.

Analysis of the data began with detailed reading of the transcripts followed by the identification of passages with recurring content, resulting in the development of provisional emergent themes. These were developed through an iterative process involving re-reading and comparison. Regular meetings with co-investigators allowed samples of the data analysis to be scrutinised, and triangulation between interviews, observations and focus group material was noted. Finally, the emergent themes were presented to the participants in order to seek feedback and confirm the validity of the study findings.

RESULTS

The study was undertaken in two teaching hospitals in the North of England. Hospital 1 has approximately 400 beds. Critical care is provided in a combined intensive care and high-dependency unit. Hospital 2 has approximately 800 beds, and has a large cardiothoracic surgery unit. Critical care services include an intensive care unit, a high dependency ward, and a separate cardiothoracic critical care unit. As a result of it's larger size and specialist services, substantially more central venous catheterisations are undertaken at hospital 2.

Twenty-seven clinical episodes were observed, in which 39 IJV cannulations were attempted and 36 central venous catheters were successfully inserted. Nine observations were in the cardiothoracic setting (in which two central venous catheters were typically inserted in the same IJV), ten were in operating theatres, four in critical care, and four in a remote site on a scheduled list of Hickman line insertions. The main operator was a consultant in 16 observations and a trainee in 11 observations. Four observations occurred in hospital 1, and 23 took place in hospital 2. In three observations landmark technique was the initial method used for locating the IJV, though this was converted to ultrasound in one instance. In 24 observations ultrasound guidance was used as the primary method, though in two of these observations the researchers view was somewhat obscured and the needling technique could not be seen in sufficient detail; these observations were therefore excluded from this analysis. No major complications were observed during the study.

Four distinct approaches to the IJV and three ultrasound techniques were seen during the observations: we have named the approaches in terms of the angulation of the needle as the *traditional landmark technique*, the *ultrasound-guided traditional approach*, *ultrasound-guided medial angulation*, and the *ultrasound-guided steep*

approach. Two of these approaches, ultrasound-guided medial angulation and the ultrasound-guided steep approach, appear unique to ultrasound-guided IJV cannulation and do not appear to have been documented in the literature thus far. We describe each of the observed techniques, providing illustrations for clarity, and have included excerpts from the recorded dialogue and observations to demonstrate the social constructs pertaining to each technique. It should be noted that combinations of techniques were observed in a few instances (e.g. medial angulation and steep approach).

'Traditional' landmark technique

In the three instances where landmark technique was observed (all consultant operators), well-established anatomical principles were adhered-to: the carotid artery was palpated and the needle inserted laterally to it, with a shallow caudal angulation and lateral intent.[3,4] Whilst observation of the landmark technique was not an objective of the study, it provides a point of reference against which the ultrasound-guided techniques can be compared.

Of particular relevance was an instance in which the operator used the landmark technique as the initial method for locating the IJV, before switching to ultrasound-guidance when the vein was not located. In this observation the vein was found to be directly superficial to the carotid artery when ultrasound was used, indicating why the insertion of the needle lateral to the arterial pulsation had failed to yield venous blood and demonstrating an advantage of ultrasound-guidance.

Despite the observable advantage of ultrasound in this instance, there was a sense amongst many consultants that the traditional landmark technique remained an important skill, and was being degraded in modern practice, thus introducing a

vulnerability that had not existed before the introduction of ultrasound. Some consultants, recognising the tension between maintaining the skill whilst adhering to guidelines, had devised methods to attempt to encourage trainees to consider the anatomical landmarks as well as using ultrasound-guidance (Excerpt 1).

C17: '…what annoys me is that they're [anaesthetic trainees] moving away from the anatomy, they don't seem to know the anatomy of the vein they're trying to cannulate. I think that's a real shame because some day they may not have an ultrasound machine available.'

Focus group with cardiothoracic anaesthetists, hospital 2

C22: 'I still like my trainees to.. know how to put a central line without ultrasound, 'cause it's a basic skill. So I always train them, putting the landmarks beforehand and then putting the ultrasound … exactly where the landmark is. I don't advise them to put the central line without ultrasound but knowing their landmarks, knowing a specific position they can put a central line without ultrasound: that's very important.'

Interview with anaesthetic consultant, hospital 1

Excerpt 1: Discussions of the Landmark Technique

Ultrasound-guided 'traditional' approach

In seven cases (six consultants, one trainee) the needle was inserted using a shallow caudad angulation with lateral intent, combined with out-of plane ultrasound-guidance. This replicates the principles of the traditional landmark technique with the addition of ultrasound.

This method was thought to be the optimum technique by a number of the cardiothoracic anaesthetists, who expressed a particular concern about approaches which adopted a medial angulation of the needle (Excerpt 2).

C15: 'I think what a lot of the trainees do is put the ultrasound beam on… so you've got the ultrasound [probe] sort-of round the side of the neck and you end up getting views where the vein's right on top of the artery. And you end up with the angle of the needle going in towards the artery (C17: yeah) and I think that's dangerous' (C17: 'yeah')…

C17: 'You see them approaching very laterally (C15: yeah, yeah). It should be coming in this direction rather than this direction.' H*e mimes lateral angulation of the needle, then medial angulation.*

C15: 'It seems to be a really common thing to do, doesn't it?'

C17: 'It's when you see the central lines on the [cardiothoracic critical care] unit. They're way over here, [*he points to the side of his neck*] where they should be up here' [*he points to the front of his neck, at the anterior edge of the sternocleidomastoid*]. (C15: 'yeah') (C24: 'yeah').

Focus group with cardiothoracic anaesthetists, hospital 2

Excerpt 2: cardiothoracic anaesthetists discussing alternative approaches to IJV cannulation.

Ultrasound-Guided Medial Angulation

In 13 cases (seven trainee operators, six consultants) the needle tip was angulated medially in the transverse plane combined with ultrasound guidance. This represents a significant departure from the traditional approach to IJV cannulation as the needle is

directed towards rather than away from the carotid artery. A representation of ultrasound-guided medial angulation can be seen in Figure 1.

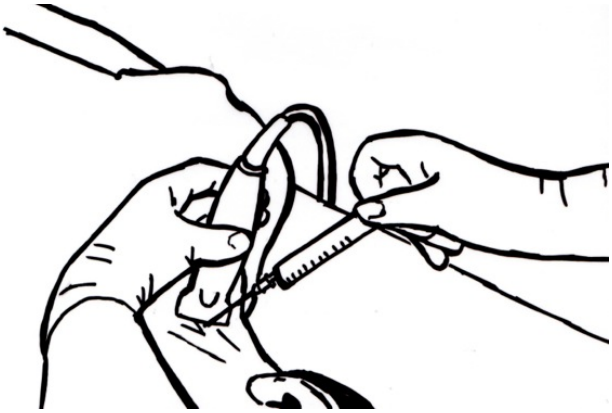

Figure 1: Illustration of medial angulation of the needle tip.

As articulated in Excerpt 2, there are concerns that the medial angulation of the needle may be a less safe approach to cannulation of the IJV due to the possibility of arterial puncture if the needle is inserted too far. Though no such complication was observed in the study, an awareness of this risk was demonstrated by a supervisor in the clinical setting (Excerpt 3).

T15: 'You're away from it, you just need to go medially, I think you're through it, you might get it on the way back.'

T14: *withdraws the needle to just below the skin, aspirating, but gets no flashback. She then angles the needle 30 degrees medially and advances it towards the vein. The lateral wall of the vein is seen to buckle on the ultrasound screen and a bright dot is seen at the apex of the buckle.*

T15: 'You're heading straight for the artery!'

Senior trainee (T15) supervising junior trainee (T14), ITU, hospital 2

Excerpt 3: Supervisor demonstrating an awareness of the risk of medial angulation.

Ultrasound-Guided Steep Approach

In nine cases (six trainees operators, three consultant) the needle was angulated steeply in relation to the surface of the skin in combination with ultrasound-guidance ('steep' was defined in our study as greater than 45 degrees). Again, this technique represents a departure from the traditional approaches. The three observations in which a consultant operator used this technique were during the insertion of Hickman lines, and were the only instances in which an in-plane ultrasound technique was observed in this study. A representation of the steep approach can be seen in Figure 2.

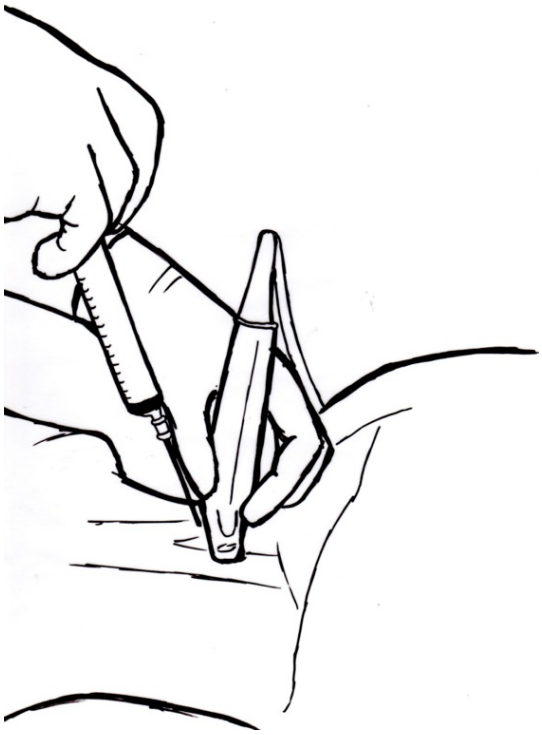

Figure 2: Illustration of the steep approach.

Though the majority of the IJV cannulations undertaken using the steep approach proceeded uneventfully, in one observation in which a trainee was attempting to cannulate an obese patient's IJV the procedure had to be aborted because of failure to

thread the catheter over the guidewire, and this was later resolved by a different operator using an ultrasound-guided traditional approach. The reason for this failure of the steep approach is open to speculation, however one hypothesis is that the guidewire, and subsequently the catheter, must negotiate a tortuous path in a patient with substantial subcutaneous tissue. This was discussed in relation to haemofiltration catheters (Excerpt 4).

C21: 'So would you change your technique for a vascath [haemofiltration catheter] compared to a central line?'

T8: 'No, because I come further back and go… I don't go in at an acute angle [to the ultrasound probe], but I think the people that do go right next to the probe and basically at ninety degrees to the skin do struggle when they come to put the vascaths in… (C19: 'yeah, cause the tract's gonna be…') … and the vascaths don't work 'cause the tract's so sort-of angled that the flows are pretty bad and they wonder why they don't work.'

C19: 'Yeah. Good point. [*she says this with a sense of discovery]*.

Focus group, anaesthetists and intensivists, hospital 1

Excerpt 4: discussion of the disadvantages of steep angulation.

Ultrasound techniques

Three discrete ultrasound techniques were utilised during the IJV cannulations observed in our study. The most frequently observed technique (22 cases) has been described as the *static out-of plane technique*.[24] This involves the ultrasound probe being placed so that a transverse image of the IJV is visible on screen and the needle being advanced perpendicularly to the plane of the image whilst the ultrasound probe is held still. In some cases the needle was visualised on-screen as a bright dot,

whereas in others distortion of the tissues was evident on the ultrasound screen but the needle was not seen.

In three cases with the same operator, the *in-plane approach* was used in which the IJV and the needle were visualised in the long axis.[24] It was evident that this was a more time-consuming and technically demanding technique as manipulation of the ultrasound probe as well as the needle was required. The entire shaft of the needle and the needle tip could be seen on the ultrasound screen, providing the operator with an enhanced awareness of the needle tip location.

In one case a *dynamic out-of-plane technique* was used.[24] This involved simultaneous manipulation of the needle and the ultrasound probe so that the image on the screen was advanced ahead of the path of the needle and then the probe was rocked back to intercept the needle tip. This technique appeared to offer an enhanced awareness of which part of the needle was being visualised when compared to the static out-of-plane technique.

In the one remaining case where ultrasound was used, the technique could not be accurately observed.

Attitudes to Risk when using Ultrasound

Whilst many consultant participants were critical of the new techniques as detailed above, a post-ultrasound change in practice to favour a more lateral point of insertion with a medial needle angulation, and a steeper approach was acknowledged amongst the consultants in the anaesthetic and ITU focus group at hospital 2, though on reflection the motives underlying their change in practice were not clear to them (Excerpt 5).

C1: …'we're obviously doing something quite different because we're putting them [internal jugular central lines] in a different place in terms of they are much more lateral. They are going through sternomastoid and that's not what we used to do. It would be interesting to know if that's more just an anaesthetic approach, to go sideways, or whether that's to do with the drapes we've got also, which gives us a small hole to work in, so people often lose the whole anatomical relationships and go 'I've got a hole, I can see a vein on ultrasound. I haven't a clue where it is but it doesn't matter.'

C31: 'What we're doing at the moment is going into the top of the vein. What we were doing was going into the medial wall… I have occasionally thought 'well should I do it?' but then you're faced with the vein and the obvious thing is:' [*he mimes inserting the needle vertically*].

Focus group, anaesthetists and intensivists, hospital 2

Excerpt 5: discussion of the change in technique since the introduction of USG

A number of participants believed that ultrasound offered a 'false sense of security', causing operators to become inattentive to other safety principles, and suggested that ultrasound-guided internal jugular cannulation could lead to higher rates of complications if used inappropriately (Excerpt 6).[20]

C10: '…I believe that it was advertised that the incidence of injuries to the patient would go down but I think it might have gone up and might still be up…'

CS: '..how do you think that occurs? That's quite interesting, that patients might be injured more often. How can ultrasound lead to that?

C10: 'Umm, false sense of security. That's what I think happens when people use ultrasound without [understanding] how exactly, how they should use it. That's all.

Interview with cardiothoracic anaesthetic consultant, hospital 2

Excerpt 6: description of the 'false sense of security' offered by USG

The diversity of ultrasound techniques was discussed in all three of the focus groups. Participants accepted the advantages of those approaches that offered the operator an enhanced appreciation of the needle tip position, however it was acknowledged that such techniques were undertaken in a minority of cases, as described in a trainee's reflections on attending an ultrasound training course run by an expert faculty (Excerpt 7).

T8: Um, I think it told me what you're actually supposed to be doing rather than what everybody does. They [the course faculty] very much went on about always seeing the end of your needle, whereas I think the way it's taught from people they don't actually see the needle as it goes into the vessel.

Focus group, anaesthetists and intensivists, hospital 1

Excerpt 7: discussion on the importance of needle tip location

The reason why operators may be hesitant to develop such techniques despite their perceived superiority was explored by participants of one focus group, who felt that the comparative ease of many central line insertions did not provide sufficient incentive to develop advanced ultrasound techniques (Excerpt 8).

C31: … that's how a lot of trainees certainly start out doing it. It's, err, target practice. 'if I can see it, [C1: Yes] it's roughly under there, I'll poke my needle at it.' [C1: Yes] And what we don't do is then refine that and do any… dynamic interaction between, you know [C1: mmm *in agreement*] tilting the probe, moving the probe, as you're

advancing the needle… whether it's because people come to [in-plane] techniques late… to look, actively look and try and define exactly where you're needle is…

C1: Is it again a problem with central lines that the easy ones are bloody easy? So you can sit there, slap your probe on and say 'Doddle. I'm in.'

Focus group, anaesthetists and intensivists, hospital 2

Excerpt 8: discussion of the barriers to the development of advanced USG techniques

DISCUSSION

In this paper we demonstrate that the introduction of ultrasound-guidance to the cannulation of the internal jugular vein has enabled the emergence of at least two associated needling methods that represent a departure from the principles of traditional landmark techniques: *ultrasound-guided medial angulation* and the *ultrasound-guided steep approach*. Whilst neither new technique is necessarily problematic, both appear to have potential disadvantages when compared to the traditional technique in certain circumstances, specifically the tortuous path of the guidewire with a steep approach, and the risk of arterial puncture if the internal jugular vein is transfixed in the case of medial angulation. The latter seems to be of particular significance given that posterior wall perforation with the needle is commonplace in out-of plane ultrasound-guided internal jugular cannulation, and this is known to be a mechanism for accidental arterial cannulation whilst using ultrasound-guidance.[25] This is of particular relevance in combination with factors such as hypovolaemia which may cause the internal jugular vein to collapse during the procedure, decreasing the target size and increasing the risk of puncturing the posterior wall, as demonstrated in Blaivas' case series of accidental arterial cannulations. [26]

A number of possible stimuli for the adoption of the new practices observed in this study were suggested. These include the ultimate requirement to place the needle into the vein which, when made visible by ultrasound, may tempt the operator to do 'the obvious thing' as discussed in Excerpt 5 – to needle the vein where it is most superficial, even if this involves sacrificing the principles of traditional central venous cannulation techniques. The 'false sense of security' articulated by study participants

may lead to a lack of consideration of needle direction or a diminution of its perceived importance due to risk compensation.[27] These factors, combined with a lack of precise descriptions of how to use ultrasound-guidance in either the primary evidence base or the guidelines subsequently derived from it create the conditions for the variation of practice.

Some operators varied their ultrasound-guided internal jugular cannulation technique deliberately to suit the patient. This was demonstrated by the consultant who altered his ultrasound technique from *in-plane* to *static out-of-plane* during the Hickman line list, and such flexibility has previously been identified as a characteristic of expert practice.[28] This can be contrasted with the rigid practice of the trainee who persisted with the *ultrasound-guided steep approach* in the obese patient despite repeated lack of success. The diversity of techniques observed in our study indicates that the clinician retains a high degree of autonomy in choosing the specifics of the ultrasound-guided internal jugular cannulation procedure, but in order to select a technique appropriately, a clinician should be aware of the range of techniques available, and their relative benefits and risks. Classifying techniques as we have done in this paper enables the succinct description ultrasound-guided internal jugular cannulation practice, facilitating the intentional selection of appropriate techniques and providing a taxonomy with which to plan procedures, act with intention,[29] and describe them precisely in medical notes, research papers, and teaching situations. It appears from our data that experts may be 'unconsciously competent' in multiple approaches to ultrasound-guided internal jugular cannulation, whereas novices may be 'unconsciously incompetent', unaware that alternative approaches may reduce risk or difficulty. By giving names to the solutions that have been developed

spontaneously by practicing anaesthetists, we hope to assist both experts and novices to move towards an enhanced awareness of their own practice, and that of others.[30] It is of relevance that although the anaesthetic training curriculum in the UK states that an anaesthetic trainee should be competent to undertake central venous catheterisation in straightforward circumstances by the end the first two years of anaesthetic training, there is no specification for exactly how this training should be undertaken.[31] In a different part of this study it was found that acquiring the skill of internal jugular cannulation is largely experiential and learning is situated in the workplace.[32] Therefore, knowledge of the techniques, advantages and pitfalls of ultrasound-guided internal jugular cannulation are of relevance to trainees and consultants alike.

Ultrasound-guided central venous cannulation is treated as a single entity in national and international guidelines but this study reveals that the real-world situation is more complex, with multiple techniques each presenting respective advantages and disadvantages.[16,17] It is a commonly observed phenomenon that results obtained in clinical trials have limited applicability in real-world clinical practice, and in a complex procedure such as internal jugular cannulation it appears highly likely that many practitioners are undertaking a procedure that is quite different from that investigated by study authors.[33] Some of the observed techniques appear to present technical challenges, and this may account for the paradoxical findings of researchers and the lived experiences of clinicians such as the participant in Excerpt 6.[20] It is well established in the literature that the introduction of 'safe' technologies may lead to unexpected consequences that if left unmitigated may diminish or even reverse their positive impact, and the data from our study provides insight into this concept.[27]

CONCLUSION

Despite the technical challenges observed in this study, neither of the new ultrasound-associated needling methods are *necessarily* problematic, and may present advantages in terms of ease of needling the internal jugular vein. A fundamental principle of ultrasound-guidance is identification of the needle tip and if this can be consistently achieved then any technique may be undertaken safely.[33] However this is known to be difficult to accomplish in practice with the out-of-plane approach as acknowledged by participants.[25] Some authors suggest that an in-plane ultrasound technique should therefore be used, in which the whole shaft of the needle is visualised, however this lacks the advantage of being able to see a cross-section of surrounding structures; others suggest a composite approach involving both in-plane and out-of-plane view, and an 'oblique axis' view, which provides in-plane needle visualisation with a view of surrounding structures, has been recently studied with encouraging results.[25, 34-37] Unfortunately the in-plane ultrasound technique is technically demanding and a change to this technique may represent an unrealistic expectation given the training burden it would represent.[38] The pragmatic recommendation is therefore to ensure that training in internal jugular cannulation does not present ultrasound-guidance as a panacea, but recognises and attempts to mitigate the potential for harm when using this technology in different ways.

A major flaw in existing clinical trials of ultrasound-guided internal jugular cannulation is the lack of adequate description of the technique used. In light of the findings of this study we suggest that authors of subsequent research papers make use of the taxonomy detailed in this paper to describe internal jugular cannulation techniques. This measure would allow readers to ascertain more precisely the

interventions under scrutiny, facilitating the translation of research into clinical practice.

LIMITATIONS

Qualitative research is concerned with obtaining an in-depth understanding of a limited number of contexts, and this project therefore cannot provide an overview of the entire scope of internal jugular cannulation practice. It is possible that if this study were repeated in further settings yet more techniques could be found and our classification cannot therefore be deemed exhaustive and further work may add to it. It is hoped that this work will stimulate discussion and further research into the real world impact of 'safe' technologies in healthcare.

REFERENCES

1] Hermosura B, Vanags L, Dickey MW. Measurement of pressure during intravenous therapy. *JAMA* 1966; 195: 321.

2] English ICW, Frew RM, Pigott JFG, Zaki M. Percutaneous cannulation of the internal jugular vein. *Thorax*. 1969; 24: 496-497.

3] Defalque RJ. Percutaneous catheterization of the internal jugular vein. *Anesth Analg.* 1974; 53: 116-121.

4] Metz S, Horrow JC, Balcar I. A controlled comparison of techniques for locating the internal jugular vein using ultrasonography. *Anesth Analg.* 1984; 63: 673-679.

5] Cook T. Litigation related to contral and peripheral venous access by anaesthetists: and analysis of claims against the NHS in England 1995-2009. *Anaesthesia*. 2011; 66: 56-57.

6] Domino KB, Bowdle TA, Posner KL, Spitellie PH, Lee LA, Cheney FW. Injuries and liability related to central vascular catheters. *Anesthesiology*. 2004; 100: 1411-1418.

7] Yonei A, Nonune T, Sari A. real-time ultrasound guidance for percutaneous puncture of the internal jugular vein. *Anesthesiology*. 1986; 64: 830-831.

8] Teichgraber UK, Benter T, Gebel M, Manns MP. A sonographically guided technique for central venous access. *Am J Roentgenol*. 1997; 169: 731-733.

9] Mallory DL, McGee WT, Shawker TH, et al. Ultrasound guidance improves the success rate of internal jugular cannulation. A prospective, randomized trial. *Chest*. 1990; 98: 157-160.

10] Nadig C, Leidig M, Schmiedeke T, Hoffken B. The use of ultrasound for the placement of dialysis catheters. *Nephrol Dial Transplant.* 1998; 13: 978-981.

11] Troianos CA, Jobes DR, Ellison N. Ultrasound-guided cannulation of the internal jugular vein. A prospective, randomised study. *Anesth Analg.* 1991; 72: 823-826.

12] Slama M, Novara A, Safavian A, Ossart M, Safar M, Fagon JY. Improvement of internal jugular vein cannulation using an ultrasound-guided technique. *Intensive Care Med*. 1997; 23: 916-919.

13] Sulek CA, Blas ML, Lobate EB. A randomized study of left versus right internal jugular vein cannulation in adults. *J Clin Anesth.* 2000; 12: 142-145.

14] Soyer P, Lacheheb M, Levesque M. High-resolution sonographic guidance for transjugular liver biopsy. *Abdom Imaging.* 1993; 18: 360-362.

15] Calvert N, Hind D, McWilliams RG, Thomas SM, Beverley C. The effectiveness and cost-effectiveness of ultrasound locating devices for central venous access. Sheffield: The School of Health and Related Research; 2002.

16] NICE. Technology Appraisal Guidance – No. 49: Guidance on the Use of Ultrasound Locating Devices for Placing Central Venous Catheters. London: NICE; 2002.

17] Lamperti M, Bodenham A, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. *Intensive care med*. 2012; 38: 1105-1117.

18] McGrattan T, Duffty J, Green JS, O'Donnell N. A survey of the use of ultrasound guidance in internal jugular vein cannulation. *Anaesthesia*. 2008; 63: 1222-1225.

19] McGrattan T, Duffty J, Green JS, O'Donnell N. A reply. *Anaesthesia*. 2009; 64: 449.

20] Mulvany SA, MacConkey C, Allen S. Ultrasound guidance and the incidence of carotid artery puncture. *International Journal of Perioperative Ultrasound and Applied Technologies*. 2012; 1: 99-101.

21] Pope C, Smith A, Goodwin D, Mort M. Passing on tacit knowledge in anaesthesia: a qualitative study. *Medical Educ.* 2003; 37: 650-655.

22] Shelton CL, Smith AF, Mort M. Opening up the black box: an introduction to qualitative research methods in anaesthesia. *Anaesthesia*. 2014; 69: 270-280.

23] Reeves S, Kuper A, Hodges BD. Qualitative research methodologies: ethnography. *Br Med J.* 2008; 337: 512-514.

24] American Institute for Ultrasound In Medicine. AIUM Practice Guideline for the Use of Ultrasound to Guide Vascular Access Procedures. Laurel: American Institute for Ultrasound In Medicine; 2012.

25] Blaivas M, Adhikari S. An unseen danger: frequency of posterior wall penetration by needles during attempts to place internal jugular vein central catheters using ultrasound guidance. *Crit Care Med*. 2009; 37: 2345-2349.

26] Blaivas M. Video analysis of accidental arterial cannulation with dynamic ultrasound guidance for central venous access. *J Ultrasound Med.* 2009; 28: 1239-1244.

27] Hedlund J. Risky business: safety regulations, risk compensation, and individual behaviour. *Inj Prev.* 2000; 6: 82-90.

28] Larsson J, Holmström IK. How excellent anaesthetists perform in the operating theatre: a qualitative study on non-technical skills. *Br J Anaesth.* 2013; 110: 115-121.

29] Anscombe GEM. Intention. Cambridge: Harvard University Press; 1957.

30] Howell WS. The Empathic Communicator. Belmont: Wadsworth; 1982

31] The Royal College of Anaesthetists. CCT in Anaesthetics Annex F – Intensive Care Medicine. Edition 2. London: The Royal College of Anaesthetists; 2010.

32] Shelton CL. Teaching and Learning with New Technology: Ultrasound-Guided Internal Jugular Cannulation [Masters Thesis]. Lancaster University; 2015.

33] Black N. Why we need observational studies to evaluate the effectiveness of health care. *Br Med J.* 1996; 312: 1215-1218.

34] Rossi UG, Rigamonti P, Tichà V, et al. Percutaneous ultrasound-guided central venous catheters: the lateral in-plane technique for internal jugular vein access. *J Vsc Access* 2014; 15: 56-60.

35] Baty G, Polan D, Nichols WL, et al. Emergency physicians more accurately identify the potentially critical posterior vessel wall needle tip location by using a long-axis orientation of the ultrasound transducer. *Ann Emerg Med.* 2008;52:S170-S171.

36] Tokumine J, Lefor AT, Yonei A, Kagaya A, Iwasaki K, Fukuda Y. Three-step method for ultrasound-guided vein catheterization. *Brit J Anaesth.* 2013; 110: 368-373.

37] Batllori M, Urra M, Romero C, Pueyo J, López-Olaondo L, Cambra K, Ibánez B. Randomized comparison of three transducer orientation approaches for ultrasound guided internal jugular venous cannulation. *Brit J Anaesth* 2016; 116: 370-376.

38] Sites BD, Spence BC, Gallagher JD, Wiley CW, Berstrand ML, Blike GT. Characterizing novice behaviour associated with learning ultrasound-guided peripheral regional anaesthesia. *Reg Anesth Pain Med.* 2007; 32: 107-115.