Investigation into the visual perceptive ability of anaesthetists during ultrasound-guided interscalene and femoral blocks conducted on soft embalmed cadavers: a randomised single-blind study

Citation for published version:
Mustafa, A, Seeley, J, Munirama, S, Columb, M, McKendrick, M-E, Schwab, A, Corner, G, Eisma, R & McLeod, G 2018, 'Investigation into the visual perceptive ability of anaesthetists during ultrasound-guided interscalene and femoral blocks conducted on soft embalmed cadavers: a randomised single-blind study', *British Journal of Anaesthesia*, vol. 120, no. 4, pp. 854-859. https://doi.org/10.1016/j.bja.2017.12.035

Digital Object Identifier (DOI):
10.1016/j.bja.2017.12.035

Link:
Link to publication record in Heriot-Watt Research Portal

Document Version:
Peer reviewed version

Published In:
British Journal of Anaesthesia

OXFORD UNIVERSITY PRESS | BJA British Journal of Anaesthesia

An investigation into the visual perceptive ability of anaesthetists during analysis of ultrasound guided interscalene and femoral blocks conducted on soft embalmed cadavers. A randomised, single blind study.

Journal:	*British Journal of Anaesthesia*
Manuscript ID	BJA-2017-01138-TAKA084.R2
Article Type:	Laboratory Investigation
Date Submitted by the Author:	19-Dec-2017
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Mesh keywords:	Regional anaesthesia, Ultrasonography, Elastography

Abstract

Background: Errors may occur during regional anaesthesia while searching for nerves, needle tips and test doses. Poor visual search impacts on decision making, clinical intervention and patient safety.

Methods: We conducted a randomised, single-blind study in a single university hospital. Twenty trainees and two consultants examined paired B-Mode and fused B-mode and elastography video recordings of 24 interscalene and 24 femoral blocks conducted on two soft embalmed cadavers. Perineural injection was randomised equally to 0.25ml, 0.5ml and 1.0ml volumes. Tissue displacement perceived on both imaging modalities was defined as "target" or "distractor".

Our primary objective was to test anaesthetists' perception of the number and proportion of targets and distractors on B-Mode and fused elastography videos collected during femoral and sciatic nerve block on soft embalmed cadavers. Our secondary objectives were to determine differences between novices and experts and between test dose volumes, and measure the area and brightness of spread and strain patterns.

Results: All anaesthetists recognised perineural spread using 0.25ml volumes. Distractor patterns were recognised in 133 (12%) of B-Mode and in 403 (38%) of fused B-Mode and elastography patterns, $P < 0.001$. With elastography, novice recognition improved from 12% to 37% ($P < 0.001$) and consultant recognition increased from 24% to 53%, $P < 0.001$. Distractor recognition improved from 8% to 31% using 0.25ml volumes ($P < 0.001$), and from 15% to 45% using 1ml volumes ($P < 0.001$).

Conclusions: Visual search improved with fusion elastography, increased volume, and consultants. A need exists to investigate image search strategies.

Introduction

Errors may occur during the visual search, recognition and decision making phases[1] of ultrasound-guided regional anaesthesia (UGRA) nerve block. Search errors are attributable to failure to see lesions that are normally noticed by anaesthetists.[2] With recognition errors, lesions are seen but confusing; and decision errors occur when a lesion is fixated on for long periods but the anaesthetist either does not recognise features or dismisses them.[3] Elastography is an ultrasound-based technology that cross-correlates radio-frequency waves before and after tissue displacement and displays relative displacement (strain) in colour. While conducting interscalene and femoral nerve block in cadavers[4] and patients[5] we noticed novel features on paired B-Mode and elastography ultrasound images in response to injection of test doses. Tissue strain intermittently presented as two patterns instead of one.[6] Additional patterns, termed distractors, were distinguished from primary target displacement patterns by brightness, size, position or movement.[7] In contrast, test doses as low as 0.25ml were always seen on B-Mode images, but distractor patterns much less so. Our impression was that elastography exhibited greater saliency, the extent to which a location differs from its surroundings, than B-mode images because: (i) key regions differed in brightness, colour, orientation, and motion; and that (ii) anaesthetists' visual attention was attracted towards these features.

Visual salience describes the visual processing mechanism that enables the brain to select important features that stand out from other items or locations[8] (Table 1). Salience is associated with passive, automatic visual search or "bottom-up processing" rather than cognitive, goal driven "top-down processing"[9]. Consideration of both processes creates an saliency map, a topographic representation of relative stimulus strength and behavioural importance. This map is distributed throughout the visual cortex and linked via the oculomotor system to eye movement and eye gaze[10]. Eye gaze characteristics such as fixations and saccades are quantified using eye-tracking technology and are used in many industries to measure technical performance.

Visual search and salience differ between experts and novices. Experts rely on bottom-up processes that facilitate efficient search, albeit mediated by prior knowledge when encountering novel stimuli[9]. Novices, in contrast, are primarily goal driven but can be salience led to very obvious targets.

We hypothesised that improvements in novice visual perception were salience driven, and, if so, would provide the evidence for investigation of the role of eye gaze technology and augmented reality during simulator training. This approach could help train anaesthetists better, target local anaesthetic more and improve patient safety.

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Methods

Participants

All trainee anaesthetists at basic, intermediate and higher levels of training working in Ninewells Hospital were invited to take part in this study along with two consultant subspecialists in regional anaesthesia. Our exclusion criterion for trainees was the prior use of elastography. The study was approved by the University of Dundee Committee on Non-Medical Ethics.

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Elastography and its applicability to the diagnosis of intraneural injection is described in detail in a previous papers[4, 6]. In summary, our engineer converted colour elastography video frames to filtered and despeckled black and white images using MATLAB software (Natik, MA) and a grayscale threshold tool. Enhanced elastography patterns were fused onto corresponding B-Mode images. Tissue displacement in response to fluid injection was seen as a flowing translucent, white area, superimposed onto paired B Mode images. Fusion videos were converted to TIFF files and analysed using ImageJ (Wayne Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, MD)

Conduct of block

A single independent, experienced anaesthetist conducted 24 interscalene and 24 femoral ultrasound-guided nerve blocks, randomised equally using a software randomisation program to 0.25ml, 0.5ml and 1ml volumes to both sides of two soft embalmed cadavers. The physical properties of the soft embalmed Thiel cadaver and its functional alignment as a simulator of ultrasound-guided regional anaesthesia have been described[6].

Interscalene block was performed using a 100 mm needle (B.Braun, Sheffield, UK), in-plane to a 5 to 10MHz ultrasound transducer, and embalming fluid deposited between the nerve roots of C5 and C6. Femoral block was performed using a 50mm needle at 90^{o} to the plane of the same ultrasound transducer and injected below the fascia iliaca and superficial to the femoral nerve. We recorded nerve blocks using a Zonare (Mountain View, CA) Z.one ultrasound scan engine build release 4.2 with B-Mode ultrasound and proprietary elastography. Blocks were recorded on DICOM imaging software.

Before starting the study, participants were shown videos of interscalene and femoral block using B-Mode and elastography ultrasound by one of two independent investigators. Participants deemed themselves ready for participation in the experiment. Each assessed 96 videos comprising 8 blocks performed at 2 sites on 2 nerves (interscalene and femoral), using 3 volumes (0.25ml, 0.5ml, 1.0ml) and 2 imaging modes (B-Mode ultrasound and fused B-Mode and elastography). Each video was played once to replicate practice. Patterns were rated according to whether perineural fluid spread or strain tissue had occurred in isolation or not. Distractors were defined as distinct patterns of spread or strain differing from target perineural spread or strain by either size, movement or time. Our primary endpoint was therefore recorded as a “1” or “2” corresponding to the number of events observed. We did not ask trainees to refine their choice further because this study focused on the detection of events and not their interpretation or impact on decision making. We did not know if sufficient homogeneity existed between patterns that would have allowed ready, simple classification by non-experts. For descriptive purposes, video examples of fluid spread and strain patterns were categorised by two researchers at the end of the study in order to minimise bias.

Area and Brightness Measurement

The cross-sectional area and brightness of B-Mode fluid spread and strain patterns were measured on every fourth video frame (every 0.5s) by a single rater using ImageJ. To test the reliability of our data, two raters independently measured the area of fusion elastograms using the yellow tracing tool available on ImageJ. Duration of fluid spread or strain was defined as the time from the first visible evidence of tissue distention to tissue relaxation. Each image was calibrated to a standard 7.28 $pixels.mm^{-2}$. Mean tissue brightness was calculated as the sum of the grey values between 0 (black) and 255 (white) of all the pixels within the region of interest divided by the number of pixels. Area and brightness measurements were log converted for analysis. Our secondary end-points were measurements of area (mm^2) and brightness.

Statistical analysis

Paired B-Mode and fused elastography images were analysed using McNemar's test and presented as differences in paired proportions. Predictors of area and brightness were assessed using a mixed effects regression model. Covariates included cadaver, right or left sided injection, injection sequence, type of block (interscalene and femoral), volume (0.25, 0.5 and 1.0ml) and imaging region of interest (perineural fluid spread, area of strain pattern). A stratified logistic regression model was used to analyse binary outcomes and take account of repeated measures. Data were analysed using Number Cruncher Statistical Systems (NCSS) 11, NCSS Inc., Kaysville, UT and LogXact 8, Cytel Inc., Cambridge, MA.

Results

Twenty anaesthesia trainees and 2 consultant UGRA experts examined 48 paired B-Mode and fusion elastography videos, giving 2112 observations. Median (IQR) trainee anaesthesia experience was 3 (1 – 4) years. All participants recognised perineural spread or strain at all volumes between 0.25ml and 1ml.

Distractors were recognised in 133 (12%) of B-Mode and 403 (38%) fusion elastography videos, differences in paired proportions, P < 0.001. (Table 2). Use of fusion elastography improved novice recognition from from 12% to 37% (P < 0.001) and consultant recognition from 24% to 53% (P< 0.001). Recognition of distractors improved from 8% to 31% using 0.25ml volumes (P < 0.001) and from 15% to 45% using 1ml volumes (P < 0.001).

Using stratified logistic regression, recognition of distractors was better with: fusion elastography Odds Ratio, OR (95%CI) 5.31 (3.14 – 8.96), P < 0.001; consultant anaesthetists OR 3.84 (2.29 - 6.45) P < 0.001; greater volumes of injectate OR 2.19 (1.11 – 4.31), P = 0.02; and worse with interscalene block OR 0.58 (0.35 – 0.94), P = 0.03 (Table 3). Area and brightness were greater with fusion elastography and with increased injectate volume (Table 4).

Three distinct strain patterns were categorised retrospectively by two additional experts in response to injection: (i) two areas of similar size, shape and brightness but spreading in opposite directions from the tip of the needle (Video 1); (ii) initial tissue displacement followed by a sudden reversal in flow and secondary displacement at the initial site of injection (Video 2); and (iii) tangential displacement away from the injection site (Video 3).

Pattern (i) was observed during 7 femoral blocks. Pattern (ii) occurred 13 times with interscalene and 5 times with femoral block, and pattern (iii) occurred once with each block.

Discussion

This study showed improved perception of distractor tissue changes using fusion elastography compared to B-Mode ultrasound. Perception was volume dependent and better with experts compared to novices and with femoral block. Learning was facilitated over a short period but not to the level of experts.

Strengths and weaknesses of the study

The principal strength of our study is that our results align with that of Awh et al[11] who proposed a framework for visual processing. We showed that a saliency-based approach using white enhancement of strain patterns and differences in volume drew attention to key targets for novices. Novice search and performance was enhanced in the short term, but has potential to speed up learning curves with repeated practice.

We extended our fusion elastography work on soft embalmed cadavers that showed that trainees were more likely to diagnose intraneural injection using fusion elastography[4]. Our current study proved more difficult because trainees were expected to recognise low volume tissue changes. Therefore, it is unsurprising that trainees could only recognise 62% of distractor patterns compared to 80% of intraneural injections as in our previous study. All trainees were able to detect perineural displacement on B-Mode images secondary to injection of volumes between 0.25ml and 1ml (videos 1 to 3), an observation that agrees with that of Krediet et al[12].

We identified three distinct distractor patterns that varied in brightness, size and movement to target patterns, and described them as bilateral, rebound and distal. Bilateral patterns occurred in 7 femoral blocks, secondary to forceful needle nerve contact during out-of-plane needle insertion (Video 1), and sideways spread of injectate. Forceful needle nerve contact and nerve haematoma has been proposed as one cause of chronic nerve damage after regional anaesthesia[13]. This observation suggests a need for investigation of the role of elastography along with pressure monitoring in the diagnosis of forceful needle verve contact. We hypothesise that rebound phenomena represented movement and reflection of fluid within fascial planes and therefore likely to contribute to clinical block. Video 2 provides an insight into the hydrodynamics of perineural spread, an aspect of regional blockade that hitherto has not been investigated. An assumption exists in practice that flow of local anaesthetic is unidirectional. Our results suggest otherwise for test doses. We hypothesise that injectate distends tissue planes, but once wavefront pressure is insufficient to open up fascial layers, it returns as a wave to the point of origin. There is a need to investigate this phenomenon further using the range of volumes used. The distal pattern seen in Video 3 is likely to be associated with excessive longitudinal strain secondary to excessive transducer pressure, albeit we would expect that local anaesthetic deposition far from the nerve would be associated with similar tissue changes. Our observations on elastography confirm previous work that suggests a potential clinical role detecting test doses. However, elastography should not be regarded as a surrogate for hydrolocation because strain area was greater than hydrolocation area on B-Mode images. Strain reflects relative displacement of all tissues during fluid injection, and tissue displacement depends on tissue elasticity or stiffness.

We used elastography as an experimental psychological tool because it demonstrated white areas of strain and spatial, temporal and dynamic changes using a standard ultrasound transducer. Injections are presented as videos because tissue change using 0.25ml to 1ml is difficult to see on static images. Use of two cadavers may be regarded as a weakness but we had limited availability at the time of the study. The University of Dundee has now converted to the whole-time use of soft embalmed cadavers and future studies will randomise to different cadavers.

Impact of Research

This work has increased understanding of the psychological mechanisms that underpin performance during nerve block. Consideration of change blindness, a perceptual phenomenon that occurs when a salient visual stimulus is introduced and the observer does not notice, suggests trainee difficulty with target search.

We hypothesise that novices were reliant on cognitive learning, which may help detect single distinctive targets, but that this compromised their performance during multiple-target search tasks because the cognitive effort needed to match targets to expectations was overwhelming[15]. In contrast, experts used an automatic global search strategy gained by long-term exposure to repeated images[16, 17]. Our results show that novices had deficiencies in visual search and that improvement in visual attention was salience driven.

Visual search is quantifiable using eye tracking, a technology used in other industries to quantify eye gaze fixations and saccades, and thus can create individual learning curves, and investigate the transfer of visual search and image interpretation to decision making[1]. We are quantifying the learning curves of trainee anaesthetists and expert regional anaesthetists while conducting up to 60 interscalene blocks on the soft embalmed Thiel cadaver in a mastery learning and dedicated practice environment. Eye gaze metrics provide a graphical representation of rate of progress, patterns of learning over time, and discrimination between good, average and poor performers, and between experts. We now wish to investigate whether eye gaze metrics, along with item analysis of preprocedural and procedural tasks provide a measure of transfer of skills from the simulator to the clinical workplace two to three months later. Using the same metrics, we also wish to investigate the best means of teaching on the simulator that translates best to practice.

An opportunity also exists to investigate which salient features are more likely to help or hinder anaesthetists and discover how novices and expert anaesthetists interrogate images and translate their impact to individual performance. The relative interaction of top-down and bottom-up influences deserves investigation in regional anaesthesia.

Conclusion

We applied fusion elastography to training on the soft embalmed cadaver to guide novice attention to salient features. This improved recognition of distractors in response to perineural test doses. A need exists to investigate novice search strategies using eye tracking technology to improve training and target local anaesthetic accurately and safely.

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Authors' Contributions and Authorship

AM Performed trainee study
JS Peformed trainee study

MC Statistical analysis
MM Psychology advisor

AS Bioengineer, wrote fusion elastography software and conducted anatomy studies
RE Supervising Anatomist
GC Medical Physics support
GM Study design, wrote paper
SM Study design, cadaver regional blocks and cadaver data collection, wrote paper

This study was presented at the Anaesthetic Research Society meeting in Clydebank, November 2016

Abstract

Background: Errors may occur during regional anaesthesia while searching for nerves, needle tips and test doses. Poor visual search impacts on decision making, clinical intervention and patient safety.

Methods: We conducted a randomized, single-blind study in a single university hospital. Twenty trainees and two consultants examined paired B-Mode and fused B-mode and elastography video recordings of 24 interscalene and 24 femoral blocks conducted on two soft embalmed cadavers. Perineural injection was randomized equally to 0.25ml, 0.5ml and 1.0ml volumes. Tissue displacement perceived on both imaging modalities was defined as “target” or “distractor”. Our primary objective was to test anaesthetists’ perception of the number and proportion of targets and distractors on B-Mode and fused elastography videos collected during femoral and sciatic nerve block on soft embalmed cadavers. Our secondary objectives were to determine differences between novices and experts and between test dose volumes, and measure the area and brightness of spread and strain patterns.

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Editor's key points

- Elastography is an ultrasound-based technology that cross-correlates radio-frequency waves before and after tissue displacement and displays relative displacement (strain) in colour.
- Compared with B-Mode ulstrasound, B-Mode plus elastography video recording may facilitate appropriate peripheral nerve blocks.

Introduction

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Statistical analysis

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(1.11 – 4.31), P = 0.02; and worse with interscalene block OR 0.58 (0.35 – 0.94), P = 0.03 (Table 3). Area and brightness were greater with fusion elastography and with increased injectate volume (Table 4).

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Strengths and weaknesses of the study

The principal strength of our study is that our results align with that of Awh et al[11] who proposed a framework for visual processing. We showed that a saliency-based approach using white enhancement of strain patterns and differences in volume drew attention to key targets for novices. Novice search and performance was enhanced in the short term, but has potential to speed up learning curves with repeated practice.

We extended our fusion elastography work on soft embalmed cadavers that showed that trainees were more likely to diagnose intraneural injection using fusion elastography[4]. Our current study proved more difficult because trainees were expected to recognize low volume tissue changes. Therefore, it is unsurprising that trainees could only recognize 62% of distractor patterns compared to 80% of intraneural injections as in our previous study. All trainees were able to detect perineural displacement on B-Mode images secondary to injection of volumes between 0.25ml and 1ml (videos 1 to 3), an observation that agrees with that of Krediet et al[12].

We identified three distinct distractor patterns that varied in brightness, size and movement to target patterns, and described them as bilateral, rebound and distal. Bilateral patterns occurred in 7 femoral blocks, secondary to forceful needle nerve contact during out-of-plane needle insertion (Video 1), and sideways spread of injectate. Forceful needle nerve contact and nerve haematoma has been proposed as one cause of chronic nerve damage after regional anaesthesia[13]. This observation suggests a need for investigation of the role of elastography along with pressure monitoring in the diagnosis of forceful needle verve contact. We hypothesize that rebound phenomena represented movement and reflection of fluid within fascial planes and therefore likely to contribute to clinical block. Video 2 provides an insight into the hydrodynamics of perineural spread, an aspect of regional blockade that hitherto has not been investigated. An assumption exists in practice that flow of local anaesthetic is unidirectional. Our results suggest otherwise for test doses. We hypothesize that injectate distends tissue planes, but once wavefront pressure is insufficient to open up fascial layers, it returns as a wave to the point of origin. There is a need to investigate this phenomenon further using the range of volumes used. The distal pattern seen in Video 3 is likely to be associated with excessive longitudinal strain secondary to excessive transducer pressure, albeit we would expect that local anaesthetic deposition far from the nerve would be associated with similar tissue changes. Our observations on elastography confirm previous work that suggests a potential clinical role detecting test doses. However, elastography should not be regarded as a surrogate for hydrolocation because strain area was greater than hydrolocation area on B-Mode images. Strain reflects relative displacement of all tissues during fluid injection, and tissue displacement depends on tissue elasticity or stiffness.

We used elastography as an experimental psychological tool because it demonstrated white areas of strain and spatial, temporal and dynamic changes using a standard ultrasound transducer. Injections are presented as videos because tissue change using 0.25ml to 1ml is difficult to see on static images. Use of two cadavers may be regarded as a weakness but we had limited availability at the time of the study. The University of Dundee has now converted to the whole-time use of soft embalmed cadavers and future studies will randomize to different cadavers.

Impact of Research

This work has increased understanding of the psychological mechanisms that underpin performance during nerve block. Consideration of change blindness, a perceptual phenomenon that occurs when a salient visual stimulus is introduced and the observer does not notice, suggests trainee difficulty with target search. We hypothesize that novices were reliant on cognitive learning, which may help detect single distinctive targets, but that this compromised their performance during multiple-target search tasks because the cognitive effort needed to match targets to expectations was overwhelming[15]. In contrast, experts used an automatic global search strategy gained by long-term exposure to repeated images[16, 17]. Our results show that novices had deficiencies in visual search and that improvement in visual attention was salience driven. Visual search is quantifiable using eye tracking, a technology used in other industries to quantify eye gaze fixations and saccades, and thus can create individual learning curves, and investigate the transfer of visual search and image interpretation to decision making[1]. We are quantifying the learning curves of trainee anaesthetists and expert regional anaesthetists while conducting up to 60 interscalene blocks on the soft embalmed Thiel cadaver in a mastery learning and dedicated practice environment. Eye gaze metrics provide a graphical representation of rate of progress, patterns of learning over time, and discrimination between good, average and poor performers, and between experts. We now wish to investigate whether eye gaze metrics, along with item analysis of preprocedural and procedural tasks provide a measure of transfer of skills from the simulator to the clinical workplace two to three months later. Using the same metrics, we also wish to investigate the best means of teaching on the simulator that translates best to practice.

An opportunity also exists to investigate which salient features are more likely to help or hinder anaesthetists and discover how novices and expert anaesthetists interrogate images and translate their impact to individual performance. The relative interaction of top-down and bottom-up influences deserves investigation in regional anaesthesia.

Conclusion

We applied fusion elastography to training on the soft embalmed cadaver to guide novice attention to salient features. This improved recognition of distractors in response to perineural test doses. A need exists to investigate novice search strategies using eye tracking technology to improve training and target local anaesthetic accurately and safely.

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Authors' Contributions and Authorship

AM Performed trainee study

JS Performed trainee study

MC Statistical analysis

MM Psychology advisor

AS Bioengineer, wrote fusion elastography software and conducted anatomy studies

RE Supervising Anatomist

GC Medical Physics support

GM Study design, wrote paper

SM Study design, cadaver regional blocks and cadaver data collection, wrote paper

This study was presented at the Anaesthetic Research Society meeting in Clydebank, November 2016

Term	Description
Visual search	Task of looking for a target in a cluttered visual environment. Non-target items are termed distractors.
Visual salience	The distinct subjective perceptual quality which makes some items in the world stand out from their neighbors and immediately grab our attention.
Guiding attribute	Visual properties that can be used to direct deployment of attention.
Saliency	The extent to which a location differs is from its surroundings with respect to guiding attributes such colour, orientation, motion
Saliency map	A topographically arranged map that represents the visual saliency of a scene.
Visual attention	The process used to select stimuli
Change blindness	Failure to notice something different about a display
Inattentional blindness	Failure to notice a fully-visible, but unexpected object because attention was engaged on another task, event, or object.
Bottom-up attention	Factors that depend only on instantaneous sensory input, without taking into account the goals, personal history and experiences.
Top-down attention	Factors that take into account goals, personal history and experiences. Bottom-up salience can be modified by top-down goals of the searcher.

Table 2. Number (n) and proportion (%) of distractor patterns identified (+) or not (-) by 20 trainees and 2 consultants on 1056 paired B-Mode and elastography images. Distractor features recognised on B-Mode images (n = 133) calculated from sum of column (a) and column (b). For example 30 (28 + 2) distractors seen on B-Mode images using 0.25mL. Distractor features recognised on elastography images (n = 403) calculated from sum of column (a) and column (c). For example 108 (28 + 80) distractors seen on elastography images using 0.25mL.

	(a) B-Mode (+) Elastography (+)	**(b) B-Mode (+) Elastography (-)**	**(c) B-Mode (-) Elastography (+)**	**(d) B-Mode (-) Elastography (-)**	**% Difference in Paired Proportions (95%CI)**	***P*-value**
Volume						
0.25 mL	28 (8%)	2 (0%)	80 (23%)	242 (69%)	22% (18 – 27)	< 0.001
0.5 mL	43 (12%)	4 (1%)	93 (26%)	212 (60%)	25% (21 – 30)	< 0.001
1.0 mL	54 (15%)	2 (0%)	105 (30%)	191 (54%)	29% (24 – 34)	< 0.001
Experience						
Trainee	104 (11%)	6 (1%)	248 (26%)	602 (63%)	25% (22 – 28)	< 0.001
Consultant	21 (22%)	2 (2%)	30 (31%)	43 (45%)	29% (19 – 39)	< 0.001
Nerve						
Interscalene	58 (11%)	7 (1%)	114 (22%)	349 (66%)	20% (17 – 24)	< 0.001
Femoral	67 (13%)	1 (0%)	164 (31%)	296 (56%)	31% (27 – 35)	< 0.001

Table 3. Stratified logistic regression model for response = 2.

Analysis takes account of repeated measures. Predictors of improved recognition were elastography, consultant anaesthetists, femoral block and increased volume.

	Univariate analysis Odd Ratio (95%CI)	**P-value**
Nerve		
Femoral	---------------------	
Interscalene	0.58 (0.35 – 0.94)	0.03
Volume	2.19 (1.11 – 4.31)	0.02
Experience		
Trainee	--------------------	
Consultant	3.84 (2.29 - 6.45)	<0.001
Mode		
B-Mode	----------------------	
Elastography	5.31 (3.14 – 8.96)	<0.001

Table 4. Cross-sectional area (mm^2) and brightness (0 – 255) of tissue displacement following injection. Geometric mean (95%CI). Measures include bifid injection and rebound effect but not distal spread. Area and brightness greater with all volumes and blocks using fusion elastography.

	Area		P-Value	Brightness		P-value
	B-Mode	**Elastogram**		**B-Mode**	**Elastogram**	
0.25ml	14.4 (9.9 – 21.0)	27.0 (18.5 – 39.3)	<0.001	28.9 (24.9 – 33.5)	94.6 (81.5 – 109.9)	<0.001
0.5ml	19.5 (13.4 – 28.5)	57.2 (39.2 – 83.4)	<0.001	27.4 (23.6 – 31.8)	129.2 (111.1 – 150.1)	<0.001
1ml	22.5 (15.5 – 32.6)	47.3 (32.7 - 68.6)	<0.001	26.2 (22.6 – 30.4)	122.9 (106.0 – 142.5)	<0.001
Interscalene	15.3 (11.3 – 20.7)	33.5 (24.6 – 45.6)	<0.001	32.9 (29.3 – 37.1)	124.9 (110.7 – 141.0)	<0.001
Femoral	22.3 (16.4 - 30.4)	52.2 (38.6 – 70.7)	<0.001	22.9 (20.3 – 25.9)	105.0 (92.8 – 118.7)	<0.001