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Citation for final published version:

Hayward, Simon, Innes, Sue and Smith, Mike ORCID: <https://orcid.org/0000-0002-4199-3315> 2022. Challenges and opportunities in point-of-care ultrasound: A qualitative exploration of respiratory physiotherapists' experiences of lung ultrasound training and its adoption in critical care. *Ultrasound* 30 (2) , pp. 126-133. 10.1177/1742271X211034199 file

Publishers page: <http://dx.doi.org/10.1177/1742271X211034199>  
< <http://dx.doi.org/10.1177/1742271X211034199> >

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# Ultrasound

**Challenges and opportunities in point of care ultrasound: A qualitative exploration of respiratory physiotherapists experiences of lung ultrasound training and its adoption in critical care.**

Journal:	<i>Ultrasound</i>
Manuscript ID	ULT-21-009.R1
Manuscript Type:	Original Research
Keywords:	lung ultrasound, Physiotherapy < Clinical speciality, intensive care, critical care, point of care ultrasound

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Manuscripts

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3 **Challenges and opportunities in point of care ultrasound: A qualitative**  
4 **exploration of respiratory physiotherapists' experiences of lung ultrasound**  
5 **training and its adoption in critical care.**  
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12 *Keywords:* thoracic ultrasound, physiotherapy, intensive care, POCUS, education  
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15  
16 **Abstract**  
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18  
19 **Introduction:** Diagnostic lung ultrasound (LUS) is gaining popularity amongst respiratory  
20 physiotherapists as an imaging modality to aid pulmonary assessments, guide intervention  
21 selection and monitor the efficacy of chosen interventions. The ability of respiratory  
22 physiotherapists to incorporate LUS into their clinical practice is influenced by multiple factors  
23 to adoption and implementation. The aim of this study was to explore the experiences of  
24 senior respiratory physiotherapists who have attempted to adopt and implement LUS into  
25 their clinical practice in critical care. It is hoped these experiences will inform the  
26 development of educational and adoption strategies for the future implementation of LUS.  
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39 **Methods:** Following a national call out, eight senior critical care respiratory physiotherapists  
40 were purposively selected to be interviewed using semi-structured questions exploring their  
41 varied experiences of LUS adoption into clinical practice on critical care. The transcribed data  
42 were thematically analysed.  
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50 **Results:** Five main themes emerged from the participants responses; (i) support for  
51 physiotherapists using LUS, (ii) knowledge and understanding of LUS evidence, (iii)  
52 governance, (iv) physiotherapists' motivation to use LUS and (v) resources. Quotes for each  
53 of the five themes are given as exemplars.  
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3 **Conclusion:** Participants reported a range of factors that influenced their ability to adopt and  
4 implement LUS into practice, several were enabling, and others were barriers to progress.  
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8 Appendix 1 contains recommendations from the authors to help guide managers and  
9 clinicians wishing to adopt LUS into respiratory physiotherapy services and patient pathways.  
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## 16 **Introduction**

17  
18 Point of care ultrasound (POCUS) is the use of focused ultrasound imaging, performed by a  
19 clinician at the location of that patient's care. Lung ultrasound (LUS) is one such type of POCUS  
20 used to assess the lung pleura and lung parenchyma. When used by treating clinicians LUS  
21 can be more accurate than chest radiograph (CXR) to diagnose respiratory conditions when  
22 patients with critical illness present with a pleural effusion, consolidation [1, 2], interstitial  
23 syndrome or pneumothorax [2]. In the United Kingdom (UK) healthcare system, respiratory  
24 physiotherapists who contribute to the assessment and management of patients with  
25 respiratory compromise do not routinely learn how to perform LUS as part of their clinical  
26 practice or undergraduate training and rely on other professionals to provide imaging on their  
27 behalf [3]. However, LUS has the potential to enhance the efficacy of pulmonary assessments  
28 by respiratory physiotherapists who are not only seeking accurate assessment methods [1, 2]  
29 but enhanced guidance for intervention selection [4] and optimal ways to monitor responses  
30 to those interventions [5].  
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51 An expanding number of UK respiratory physiotherapists are learning LUS and performing LUS  
52 scans themselves as autonomous practitioners [3]. However, the number of LUS accredited  
53 respiratory physiotherapists in the UK remains very low at around 15 individuals (at the time  
54 the interviews were performed). If more respiratory physiotherapists are to adopt LUS into  
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3 their practice in critical care as an advanced skill, then prior knowledge of the experiences  
4  
5 from their peers may better inform those considering using this imaging modality.  
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8  
9 In our recent national survey exploring the use of LUS by respiratory physiotherapists [6],  
10  
11 several factors emerged that influenced, both positively and negatively, the respondents'  
12  
13 ability to adopt LUS. Some of the factors such as "availability of a machine" or "availability of  
14  
15 training" were self-explanatory. However, other factors such as "team support", "time  
16  
17 pressures", "evidence" and "governance" covered overly broad areas. This study aims to  
18  
19 explore these broader factors in more depth using semi-structured interviews. The aim of this  
20  
21 research is to extend our understanding of respiratory physiotherapists' LUS experiences to  
22  
23 inform the development of educational and adoption strategies for the future adoption of  
24  
25 LUS by respiratory physiotherapists.  
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## 31 **Methods**

### 32 **Research Design**

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35 This study used qualitative research methodology through semi-structured interviews to  
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37 explore and capture the individual experiences of respiratory physiotherapists who had  
38  
39 begun the process of implementing LUS into their clinical practice in critical care. The  
40  
41 qualitative paradigm supported by inductive reasoning provided an appropriate framework  
42  
43 for data collection and analysis; data reflecting participants' experiences and beliefs creates  
44  
45 actionable knowledge that can underpin innovation and policy development [7]. Findings  
46  
47 from our previously published national survey [6] were used to inform both the participant  
48  
49 selection process and the semi-structured interview questions by identification of concepts  
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51 for exploration and elaboration.  
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## Participant selection

Following a call out in the UK respiratory physiotherapy special interest group newsletter (potential readership of 1400 physiotherapists) a total of 24 individuals volunteered for the study. The volunteers completed a short online survey where they ranked, in order of priority, the influence of the four factors that had emerged from our previous national survey: team support, time pressures, the evidence base and governance [6]. A purposive sampling strategy was used to select eight interview participants by selecting two participants, from each of the four factors, who had ranked that factor as their highest priority. This process did not aim to be statistically representative but informationally representative and accesses subjects based on preselected parameters of central importance to the research question [8].

Due to there being only one dedicated LUS course for respiratory physiotherapists adopting LUS in the UK seven of the eight participants had previously completed a 1-day introductory LUS course with the lead author. No further direct training with the participants occurred beyond that 1-day introductory course with all participants subsequently spending all of their training with either their mentors or other LUS users not connected to this study (Figure 1).

At the time of their interviews, three of the participants had successfully gained their LUS accreditation; the remaining five were progressing towards completion. All participants were following the LUS module from the UK Intensive Care Society's Focused Ultrasound in Intensive Care (FUSIC) training programme [9].

[Insert Figure 1.]

## Data collection

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2  
3 The authorship team developed the interview questions collaboratively and a topic guide was  
4 devised (Appendix 2) to ensure interviews explored key concepts having been informed by  
5 issues identified from our previous national survey [6] and the research aims. One pilot  
6 interview was undertaken. This pilot participant provided feedback on interview content.  
7  
8 Whilst no changes were made to topics covered in the interview, minor amendments were  
9 made to some questions to optimise clarification, the pilot data obtained was not included in  
10 the final analysis.  
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21 All eight participants were interviewed by one author (SI), a physiotherapist and an  
22 experienced qualitative researcher in healthcare, education and POCUS but no previous LUS  
23 experience, and who was not known to the participants prior to the interview. The interviews  
24 took place by telephone, field notes were taken, and the interviews were digitally recorded  
25 and transcribed verbatim. All data were pseudo-anonymised; participants were given a study  
26 identification number and all study information was kept on password protected storage  
27 drives. The transcribed data were verified by two authors (SH), a respiratory physiotherapist  
28 and researcher in LUS, and the interviewer (SI).  
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#### 41 **Data analysis**

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44 The transcribed data were analysed thematically (facilitated by MAXQDA, Version 11, VERBI  
45 Software, Consult-Sozialforschung GmbH, Berlin, Germany). This inductive process was driven  
46 by the study's exploratory nature; themes were identified from the analysis [10] rather than  
47 preceding it. Initial coding, guided by the principles of Saldaña [11] was followed by formation  
48 of sub-categories, categories and finally, themes. On completion, alignment with key factors  
49 identified in our previously published national survey was noted [6]. Adequate participant  
50 recruitment and content validity were verified by the many indications of data saturation  
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observed; replication of the study was achievable, further coding was no longer feasible and the analysis process enabled new emergent information [12]. The thematic analysis process followed six steps: familiarising yourself with your data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report [13]. Coding and theme formation were conducted by one researcher, (SH), and verified by a second researcher, (SI).

## Results

A total of eight participants were recruited to the study. The interview durations ranged from 40 to 60 minutes. All participants worked either full-time or part-time in a critical care environment and had at least five years' experience in this specialist area. Other participant demographics are presented in Table 1.

**Table 1: Demographics of interview participants: healthcare employment level, responsibilities and completion of accreditation.**

Participant (PT)	NHS* Band	Responsibilities	LUS accredited
1	7	Clinical	No
2	8b	Clinical & academic	No
3	8a	Clinical & managerial	No
4	6	Clinical	Yes
5	8a	Clinical & managerial	Yes
6	8a	Clinical	No
7	7	Clinical	No
8	7	Clinical	Yes

\* NHS: National Health Service. NHS band reflects seniority, newly qualified staff are band 5, consultant physiotherapists are band 8b.

Data analysis resulted in the identification of five over-arching themes, each one reflecting a key element that participants highlighted that related to the research topic. The themes were named to reflect the essence of their content:



- 1
- 2
- 3 1. Support for physiotherapists utilising LUS
- 4
- 5
- 6 2. Knowledge and understanding of LUS evidence
- 7
- 8
- 9 3. Governance
- 10
- 11
- 12
- 13 4. Physiotherapists' motivation to use LUS
- 14
- 15
- 16 5. Resources
- 17
- 18
- 19
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- 22

23 Each theme's key findings have been summarised and exemplar quotations from participants  
24 have been supplied for each theme.

#### 25 *Theme 1, 'Support for physiotherapists' utilising LUS'*

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32 Most participants reported a positive experience of support from physiotherapy  
33 management, peers, senior medical professionals (i.e. consultant anaesthetists) and the  
34 wider multidisciplinary team (nurses and advanced critical care practitioners). LUS was  
35 viewed as an advantageous skill for respiratory physiotherapists to acquire by those with a  
36 good understanding of the technique.  
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45 *"We discussed it when we started training with the clinical lead and the ITU*  
46 *manager.....we don't embark on silly endeavours, they know what we are implementing is*  
47 *always with the patient's best interest at heart."* (PT3)  
48  
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52  
53 If participants experienced any barriers to LUS adoption it almost exclusively originated from  
54 their own physiotherapy management. The reasons for this hesitation usually revolved  
55 around concerns about complaints and litigation.  
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3                   *"I think it's a skill they don't really understand, it's not something that a lot of physios*  
4 *are doing so if I did something wrong, I think they are worried about the repercussions."* (PT7)  
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11 *Theme 2, 'Knowledge and understanding of LUS evidence'*  
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14 Some participants stated that whilst the evidence for respiratory physiotherapists' application  
15 of LUS is limited, they were frustrated if colleagues suggested this small evidence base was  
16 justification for not engaging with the modality. Participants were keen to articulate that  
17 there was an emerging respiratory physiotherapy evidence base for LUS, and much of the  
18 wider evidence base for LUS was directly relevant to respiratory physiotherapy practice with  
19 no evidence to suggest these techniques should not be used.  
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29                   *"I think as long as you can justify the clinical benefit....so the absence of evidence is not*  
30 *a worry for me, it's an absence of positive evidence as much as an absence of negative*  
31 *evidence....it's whether you see it's balanced. You know if we waited for evidence for*  
32 *everything that we do, I don't think we would do very much."* (PT6)  
33  
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40 Some participants were keen to contribute to quality improvement projects and clinical  
41 studies, whilst others regarded their personal priority was to learn and practice LUS skills but  
42 acknowledged that a strong evidence base would facilitate wider acceptance and adoption.  
43  
44  
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48                   *"We are making our own evidence; it is obviously not strong robust RCT (randomised*  
49 *controlled trial) type stuff, but we are making enough of a case for good practice that it is*  
50 *being useful...."* (PT3)  
51  
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60 *Theme 3, 'Governance'*

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3 The theme of governance was drawn together from content that had been categorised with  
4 the terms 'clinical effectiveness', 'education' and 'risk management'.  
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9 *Category - Clinical effectiveness*  
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12 Every participant commented that in their experience, LUS provided quick, accessible  
13 information that enabled different pathologies to be identified to aid differential diagnosis,  
14 enhance physiotherapy efficiency, and resource management. Participants observed that LUS  
15 contributed to the clinical reasoning process enabling them to clarify if physiotherapy was  
16 indicated for a patient at a given point in time and to ensure that the patient was directed  
17 along the correct medical or physiotherapy treatment pathway.  
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26  
27 *"...we see changes on the x-ray, the differential diagnoses are either collapse,*  
28 *consolidation or pleural effusion and we treat and treat and treat, and actually underlying all*  
29 *of this was a significant pleural effusion and we've invested a lot of therapy time when the*  
30 *optimum treatment wasn't initiated." (PT1)*  
31  
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38 The ability to evaluate efficacy of treatment interventions was rated highly by several  
39 participants. They placed value on scanning before and after a therapeutic intervention to  
40 obtain immediate feedback regarding an intervention's efficacy.  
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43  
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45 *"...if we assess in our normal assessment, we can then ultrasound, perform the treatment and*  
46 *then re-ultrasound. So, for all those kinds of typical ITU physio treatments, we have got a*  
47 *before and after comparison then." (PT3)*  
48  
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53 Similarly, the use of LUS over time to monitor patients' improvement or deterioration was  
54 highly regarded.  
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58  
59 *"I find it really useful for serial scanning..... you can track changes quite easily." (PT4)*  
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6 Some participants highlighted that if a single clinician conducted the LUS whilst undertaking  
7  
8 their assessment of a patient, there were advantages. They reported that LUS information  
9  
10 was analysed in a manner that is coherent with the professional's clinical reasoning and  
11  
12 immediately considered alongside the other respiratory physiotherapy assessment findings.  
13  
14  
15

16  
17 *"...if I'm doing the full assessment myself, I'm looking at the chest I'm looking at the*  
18  
19 *bloods I'm looking at the patient themselves and doing their obs (observations) I'm doing the*  
20  
21 *scan itself I'm taking all that information and analysing that myself in that one moment. I'm*  
22  
23 *not trying to interpret something that was done a few hours before which may or may not be*  
24  
25 *the case now anyway." (PT4)*  
26  
27

#### 28 29 *Category – Education, mentoring and competency*

30  
31  
32 Education was discussed by every participant; they all reported that high quality education  
33  
34 must underpin the adoption of LUS. Whilst the mentored scanning requirements were valued,  
35  
36 several participants struggled to find a suitably skilled professional to support their learning.  
37  
38  
39

40  
41 *"So, there is no easy access to anyone that is a FUSIC (Focused Ultrasound in Intensive*  
42  
43 *Care) mentor....whilst you can learn how to use the ultrasound machine, how to hold the*  
44  
45 *probe, you can't get that real time feedback to what you are seeing.... everything you would*  
46  
47 *normally like to do when you learn a new skill." (PT6)*  
48  
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#### 50 51 *Category - Risk management*

52  
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54 Participants highlighted that safe practice was key. This needed to be within their own  
55  
56 professional scope of practice and that imaging information should only be used to support  
57  
58 respiratory physiotherapy specific management or communicated to other team members if  
59  
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3 indicated. Participants drew on publications from their professional body to support this but  
4  
5 some regarded gaps in professional framework documentation and other guiding policies that  
6  
7 require addressing in the future.  
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#### 10 11 12 13 14 15 *Theme 4, 'physiotherapists' motivation to use LUS'*

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18 The participants reported their motivation to engage with LUS was underpinned by 'personal',  
19  
20 'physiotherapy profession' and 'patient' related factors. On a personal basis, several  
21  
22 participants articulated a desire to invest in their own development and take pride in their  
23  
24 achievements. Sometimes, the drive for this development was framed by challenges to  
25  
26 progress along a formal career path as promotion opportunities were described as restricted.  
27  
28 A more common personal motivation was the participants' desire to enhance their own  
29  
30 professional reputation and to be viewed by patients and multi-disciplinary team members  
31  
32 as practitioners with a high level of credibility who have extended their skill set and scope of  
33  
34 practice.  
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40  
41 *"There are not really that many opportunities for me to expand or kind of go up in*  
42  
43 *grades, we don't have any consultant posts, we don't have any specialist posts, so I feel that*  
44  
45 *lung ultrasound is an opportunity for myself, who is someone quite senior, you know, quite*  
46  
47 *experienced to continue that development" (PT1)*  
48  
49

50  
51 The interview content for 'physiotherapy profession' related motivation reflected opinions  
52  
53 regarding their professional suitability in using LUS as respiratory physiotherapists to assess,  
54  
55 guide treatments and monitor the lung as a major component of their clinical role.  
56  
57 Observations were made that the culture of acceptance appeared to be expanding and some  
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3 predicted that in a short period of time, respiratory physiotherapists based on critical care  
4  
5 units should expect to regard LUS as part of standard practice.  
6  
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8  
9 *“We consider ourselves to be experts in the assessment of a chest patient, so for us it’s*  
10  
11 *having an additional tool that we’ve got in addition to all the other skills.” (PT2)*  
12  
13

14 Under ‘patient’ related motivations a small number of participants observed that in some  
15  
16 circumstances, patients’ understanding of their condition and engagement with treatment  
17  
18 may be enhanced by witnessing the LUS imaging process in action.  
19  
20  
21

22  
23 *“I think a patient who is....awake and understands what you are doing, they give it*  
24  
25 *more credibility from a physio perspective if you are doing an ultrasound and you can tell them*  
26  
27 *the results of the ultrasound. So, they look upon the machinery and what you are doing I think*  
28  
29 *as something a bit more credible...” (PT5)*  
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### 37 *Theme 5, ‘Resources’*

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39 Participants all reported resourcing issues that impacted their LUS education and ability to  
40  
41 adopt LUS into clinical practice. They noted that during their training, responsibilities to  
42  
43 routine clinical and managerial duties affected their progress. Other resource requirements  
44  
45 included the availability of a suitable ultrasound system and as discussed previously, access  
46  
47 to a qualified mentor.  
48  
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52  
53 *“That’s one of the things I find so difficult because I am so busy as a clinician, and with*  
54  
55 *my other roles....especially with all of the issues with finding yourself a mentor....so its things*  
56  
57 *like that I find difficult.” (PT2)*  
58  
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3 Some participants reflected that they viewed the time committed to training as an investment  
4 that brought resource efficiencies to their current clinical work as adopting LUS into practice  
5  
6 had resulted in faster clinical assessment and treatment times.  
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9  
10  
11 *“...to say, ‘this is what I think will make this patient better’ and therefore make them*  
12 *be able to wean off the ventilator and therefore rehab, have a better patient outcome. I think*  
13 *this is really important and I think we have an important role to play within that.” (PT1)*  
14  
15

16  
17  
18 A small number of participants suggested that resources associated with LUS adoption  
19 warranted protection e.g. financial support for equipment, as once training had started, it  
20 was frustrating and wasteful not to complete it.  
21  
22

23  
24  
25 *“...we are looking at trying to get more ultrasound machines as we have only got one*  
26 *at the moment and if it is needed....or a doctor is using it for putting lines in....then we may*  
27 *not have access to the machine.” (PT8)*  
28  
29

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31  
32 Participants in part-time managerial roles placed emphasis on the need to select  
33 appropriately skilled staff for LUS training. There was a consensus that LUS was suited for  
34 respiratory physiotherapists with significant specialist experience in a respiratory discipline  
35 and not for newly qualified or non-qualified staff. Their view was that respiratory  
36 physiotherapists should be experienced senior clinicians with well-established clinical skills to  
37 enable effective LUS adoption.  
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## 50 51 52 53 54 **Discussion**

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57 This study is, to the authors’ knowledge, the first to explore the experiences of respiratory  
58 physiotherapists training and adoption of LUS into their clinical practice on critical care.  
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3 Within the five themes formed from the interview data: (i) support for physiotherapists  
4 utilising LUS, (ii) knowledge and understanding of LUS evidence, (iii) governance, (iv)  
5  
6 physiotherapists motivation to use LUS, and (v) resources, participants reported a range of  
7  
8 factors that influenced their ability to adopt LUS into practice, several were enabling, and  
9  
10 others were barriers to progress.  
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16 Enabling factors from within the themes included support from senior clinicians, peers,  
17  
18 colleagues and mentors, motivation for personal and professional development, optimal  
19  
20 patient care and efficient allocation of resources including time. Barriers included difficulty  
21  
22 accessing mentorship, lack of machine availability, limited time to train, lack of governance  
23  
24 clarity and reluctance from some managers to support LUS adoption. These factors are  
25  
26 strongly aligned to previously published literature that has explored allied health  
27  
28 professionals' ability to adopt other ultrasound techniques (14-16). A summary of this study's  
29  
30 recommendations and future considerations can be found in Appendix 1.  
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### 36 *Support for physiotherapists using LUS*

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40 Support for respiratory physiotherapists adopting LUS was as anticipated from the sample  
41  
42 recruited, almost universal. If any group had reservations it was those responsible for  
43  
44 managing the respiratory physiotherapists looking to adopt LUS. This is understandable  
45  
46 especially if managers are unfamiliar with ultrasound imaging and considering LUS is not a  
47  
48 modality commonly used by respiratory physiotherapists and would benefit from additional  
49  
50 physiotherapy specific LUS guidance.  
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### 55 *Knowledge and understanding of LUS evidence*

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3 Participants in this study evidenced knowledge and understanding of LUS but research to  
4 support its application by respiratory physiotherapists is limited. This study's interview data  
5 highlighted that some participants were willing to engage in building the LUS evidence base.  
6  
7 Potential studies could explore the effect of LUS on clinical outcomes or respiratory  
8 physiotherapists' clinical reasoning processes. Additional respiratory physiotherapy specific  
9 research questions could include evaluation of sonographic features pre and post respiratory  
10 physiotherapy intervention with the aim of establishing content validity of LUS's application  
11 as an outcome measure.  
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### 23 *Governance*

24 Participants in this study universally reported that they viewed LUS as a promising monitoring  
25 tool and described its role before and after therapeutic interventions as well as serial scanning  
26 over consecutive treatment session. Professional innovation underpinned by education and  
27 consideration of governance issues should underpin future research studies and specific  
28 guidance related to physiotherapy led LUS.  
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### 39 *Physiotherapists' motivation to use LUS*

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42 The study's participants evidenced their willingness to engage with post-registration  
43 education to extend their skill set with the intentions of improved patient engagement as well  
44 as professional and personal development opportunities. A paucity of research however has  
45 been undertaken regarding development opportunities for respiratory physiotherapists [17],  
46 but it may be considered prudent for employment retention strategies for this specialist  
47 group to align with opportunities for professional development such as LUS.  
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### 57 *Resources*

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3 Prior to initiating LUS training, resources such as protected time away from other  
4 responsibilities to complete the programme, access to ultrasound equipment and access to  
5 regular mentorship should be established. Mentorship in non-physiotherapy ultrasound  
6 training programmes has been reported as a challenge [15, 18-19] as well as within  
7 physiotherapy [6, 14]. This study's participants reinforced the mentorship requirement, and  
8 despite the difficulties, no participant suggested that educational strategies were  
9 inappropriate or that requirements should be reduced.  
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24 Any expansion of the respiratory physiotherapy LUS professional group should facilitate  
25 opportunities to further explore applications of LUS that may be unique to the profession;  
26 governance issues will need to be addressed and with greater exposure to LUS, this emerging  
27 group of clinicians should aim to support research that will further develop and clarify the  
28 respiratory physiotherapists professional relationship with this emerging imaging technique.  
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37 The participants in this study have reflected positively on their engagement with LUS, they  
38 have provided a range of applications related to the critical care environment, but it is evident  
39 LUS should not be restricted to this one clinical area. Similarly, it is highly improbable that the  
40 list of clinical applications identified by these participants is exhaustive. This is an emerging  
41 application, and the full extent of its clinical value has yet to be ascertained.  
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### 50 **Strengths and limitations**

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54 Participant recruitment strategies brought both strengths and limitations to this study; it  
55 effectively recruited participants who had early experiences of adopting LUS, but it is  
56 acknowledged that the three participants accredited in LUS (out of a UK wide total of 15) and  
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3 the remaining five participants (ongoing LUS training) is a restricted population and will have  
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5 affected the diversity of explored experiences and may not be representative of the views of  
6  
7 all respiratory physiotherapists. It is acknowledged that with seven of the eight participants  
8  
9 having attended the author's 1-day LUS course their responses may align with the author's  
10  
11 teaching content, but the participants are experienced clinicians and consumers of empirical  
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13 evidence from many sources during their LUS education beyond a single day's training.  
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19 This study's strengths include the purposive sampling strategy that accessed participants for  
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21 selected criteria informed by the previous national survey [6], also the rigorous thematic  
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23 analysis and the impact of the research team's professional experience.  
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26  
27 The interviewer's professional background as a physiotherapist enabled access to this  
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29 material and it is probable that a non-physiotherapist clinician would not have had the  
30  
31 appropriate familiarity with governance related or professional terminology. As the  
32  
33 interviewer had no LUS experience, this data collection process was framed with genuine  
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35 academic curiosity without the potential of bias from preconceptions.  
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## 39 **Conclusion**

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43 This study has explored respiratory physiotherapists' experiences of learning LUS and factors  
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45 that affected their adoption of this modality in critical care units. Participants reported  
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47 noteworthy enthusiasm for LUS, but a range of factors had influenced their engagement with  
48  
49 it. As an example of POCUS and an emerging imaging modality for respiratory  
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51 physiotherapists, it is evident that the adoption of LUS needs to be framed by rigorous clinical  
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53 governance. This POCUS application is relatively new and shows potential for the  
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55 physiotherapy profession [3, 20]. Individual clinicians, educational institutions and  
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3 professional bodies must ensure its adoption and utilisation by respiratory physiotherapists  
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5 is underpinned by professionalism and robust measures. It is evident that this study's  
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7 participants value the professional development opportunities and clinical impact of this  
8  
9 modality. Whilst these participants represent a small cohort from a niche professional group,  
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11 they have highlighted that the use of LUS by physiotherapists warrants further exploration to  
12  
13 facilitate education, clinical integration and its optimal application by physiotherapists.  
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### 22 **Ethical approval**

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25 Ethical approval was awarded by Ethics Committee, Faculty of Science and Health, The  
26  
27 University of Essex, reference number: SRES 1871.  
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### 34 **Funding sources**

35  
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37 This research did not receive any specific grant from funding agencies in the public,  
38  
39 commercial, or not-for-profit sectors.  
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### 43 **Declaration of Conflicting Interests**

44  
45  
46 The authors declared no potential conflicts of interest with respect to the research,  
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48 authorship, and/or publication of this article.  
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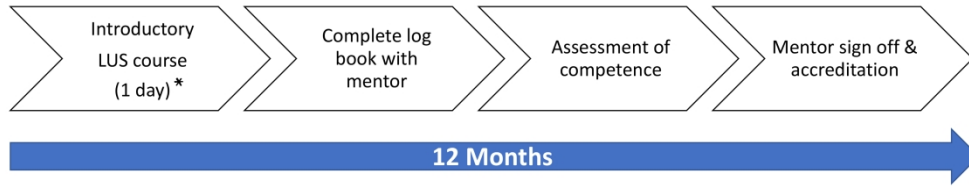


Figure 1. Example flowchart of a typical point of care lung ultrasound accreditation journey.  
 \*includes didactic and hands on practical lung ultrasound teaching.

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**Appendix 1: Summary of key points and recommendations.**

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Theme	Category	Key finding's impact on Physiotherapists' adoption of LUS	Recommendations
<p><b>Support for physiotherapists using LUS</b></p>	<p>Organisation</p>	<p>The MDT generally supported physiotherapists' adoption of LUS.</p> <p>Pre-existing professional relationships were significant enablers.</p> <p>Communication regarding the remit of scanning was key.</p>	<p>Frameworks needs to be developed and published to guide how organisations and MDT members can support LUS for physiotherapists</p> <p>All stakeholders may seek advice from colleagues in other critical care units who have already adopted LUS into practice.</p> <p>Framework needs to be developed and published to guide how open communication can ensure all parties agree the remit of LUS adoption by physiotherapists in clinical environment.</p>
	<p>Physiotherapy department</p>	<p>Some physiotherapy managers may be cautious regarding the professional considerations and potential legal implications.</p>	<p>Physiotherapy managers and clinicians should seek advice from colleagues who have already adopted LUS into practice.</p> <p>Publication of guidance, e.g. frameworks to clarify professional considerations related to physiotherapists' adoption of LUS.</p>
<p><b>Knowledge and understanding of LUS evidence</b></p>	<p>Evidence base</p>	<p>The limited formal evidence base related to physiotherapists' use of LUS can be regarded as a barrier to its adoption.</p>	<p>Regularly review the expanding evidence base for relevance, transferability and applicability:</p> <ul style="list-style-type: none"> <li>• Research conducted by other professions in LUS</li> <li>• Publications related to ultrasound imaging by physiotherapists in other specialisms</li> <li>• Publications related to LUS by physiotherapists</li> </ul> <p>Proactive participation in opportunities to extend the evidence base:</p> <ul style="list-style-type: none"> <li>• Local audit/service evaluation/Quality Improvement</li> <li>• Participation in professional groups to develop policy</li> <li>• Formal clinical research, (collaborate with colleagues in Higher Education Institutions)</li> </ul> <p>Proactive sharing of evidence:</p> <ul style="list-style-type: none"> <li>• Publish and present at conferences, (collaborate for support)</li> <li>• Contribute to professional networks</li> <li>• Establish peer support groups for knowledge exchange</li> </ul>

<p>1 2 3 4 5 6 7 8 9 10 11</p>	<p>Department understanding of LUS</p>	<p>Adopting a new technique, approach, technology or intervention necessitates addressing a sharp learning curve. Development is not possible without learning and strategies to evaluate value.</p>	<p>Clinicians may draw on support from professional and regulatory bodies.</p> <p>Clinicians may need to recruit support strategies to facilitate the process of linking theory to new practice:</p> <ul style="list-style-type: none"> <li>• Establish peer support groups for knowledge exchange</li> <li>• Set up collaborations, e.g. with Higher Education Institutions to support audit, clinical research and sharing of findings.</li> </ul> <p>Quality Improvement (QI) theory may provide guidance.</p>
<p>12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32</p>	<p><b>Governance</b>  Clinical effectiveness</p>	<p>High sensitivity and specificity of LUS when compared to other imaging.</p> <p>No ionising radiation so can be used for serial scanning.</p> <p>Integrated into practice to facilitate clinical decision making</p> <p>Tool to quickly evaluate efficacy of interventions.</p>	<p>Clinicians to draw on:</p> <ul style="list-style-type: none"> <li>• Formal clinical data and personal observations</li> <li>• Evidence relating to physiotherapists' adoption of LUS and transferable evidence</li> </ul> <p>Publication of guidance, e.g. relevant frameworks and publications from professional and regulatory bodies.</p>
<p>33 34 35 36 37</p>	<p>Education</p>	<p>Existing education pathways are effective but support and mentorship can be difficult to access</p>	<p>Evaluation of existing education pathways.</p> <p>Liaison between education providers and professional bodies for coherency and strategies to enhance mentorship opportunities.</p>
<p>38 39 40 41 42 43 44 45 46</p>	<p><b>Physiotherapists' motivation to use LUS</b>  Personal motivation</p>	<p>Clinical risk, (direct harm) from LUS is very low.</p> <p>Managers are wary of indirect harm – imaging and communication errors.</p> <p>Professional career development.</p> <p>Enhancement to professional satisfaction and stimulation.</p>	<p>Publication of guidance, e.g. relevant frameworks and publications from professional and regulatory bodies.</p> <p>Individual clinicians may need to create as well as respond to professional development opportunities.</p>
<p>38 39 40 41 42</p>	<p>Physiotherapy specific motivation</p>	<p>LUS aligns with respiratory physiotherapist's assessment and management processes.</p>	<p>Clinical research required to evaluate efficacy of LUS with critical care patient population.</p> <p>Publication of guidance, e.g. relevant frameworks and publications from professional and regulatory bodies.</p>

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2	Patient related motivation	LUS may contribute to patient education, management adherence and clinical outcomes.	Qualitative research required to evaluate the impact of LUS on the patient experience.
3	<b>Resources</b>		
4	Accessing mentorship and time to train	Competing demands on time present a challenge to accessing LUS education and mentorship.	Research that evaluates and demonstrates the efficacy of LUS implementation by physiotherapists is key to rationalisation of training priorities.
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7	Time: efficient use	LUS regarded as time effective resource	Clinical data exploring impact on work efficiency required.
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11	Equipment	Some physiotherapists were competing with other MDT members for equipment on critical care units.	Research that evaluates and demonstrates the efficacy of LUS implementation by physiotherapists is key to equipment procurement.
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## Appendix 2: Interview topic guide

Thank you for agreeing to take part in this interview.

As you are aware we are exploring the factors that affect the implementation of diagnostic thoracic ultrasound into respiratory physiotherapist's clinical practice. These questions have been created to explore, in detail, some of the factors raised by our previous national survey.

As this interview is being conducted by telephone / Skype etc, and we are not face to face please do not feel you need to rush your answers – you may want a little thinking time.

This interview is being recorded. Can we proceed?

Can you tell me about your experience of thoracic ultrasound to date?

What role(s) do you think thoracic ultrasound has for respiratory physiotherapists?

- Why?

I'd like to talk about "team support" in regards to physiotherapists using thoracic ultrasound:

- Have you received any support or opposition from senior management?
  - Support – impact on practice
  - Opposition – impact on practice
  - Has there been any response or action to the support or opposition?
- Have you received any support or opposition from other physiotherapy colleagues?
  - Support – impact on practice
  - Opposition – impact on practice
  - Has there been any response or action to the support or opposition?
- Have you received any support or opposition from non-physiotherapy colleagues?
  - Support – impact on practice
  - Opposition – impact on practice
  - Has there been any response or action to the support or opposition?

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3 A very common reported factor in our survey that limits physiotherapists implementing thoracic  
4 ultrasound into clinical practice was “time pressures”.

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- 8 • Have any ‘time pressures’ affected your implementation of thoracic ultrasound into clinical  
9 practice? (Probe re staffing levels, clinical pressures, educational demands, access to  
10 mentorship. Impact on personal experience and impact on profession in general)
  - 11 • How might these issues be addressed?
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15 One factor raised in our previous survey was the lack of understanding or a lack evidence to support  
16 the use of thoracic ultrasound.

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- 19 • In your opinion what ways could “a lack of understanding” affect the implementation of  
20 thoracic ultrasound into clinical practice?
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  - 23 • In your opinion what ways could “a lack of evidence” affect the implementation of thoracic  
24 ultrasound into clinical practice?
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  - 27 • How might this issue be addressed?
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33 I’d like to now talk about governance in relation to physiotherapists using thoracic ultrasound.

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- 35 • Have you encountered any factors or have any opinions relating to thoracic ultrasound  
36 education for physiotherapists? (course content, structure, competency, CPD)
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  - 39 • Have you encountered any factors or have any opinions relating to thoracic ultrasound  
40 regulation for physiotherapists? (indemnity, registration, accreditation)
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  - 43 • Have you encountered any factors or have any opinions relating to thoracic ultrasound  
44 utilisation for physiotherapists? (professional remit/boundaries, scope of practice,  
45 accountability, quality assurance)
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We appreciate your feedback and also you giving us the opportunity to revise our manuscript again. All authors have agreed to the recommended changes and re-reviewed the manuscript. Many thanks for the helpful changes offered below.

**Reviewer: 1**

Comments to the Author	Author response
<b>Title:</b> Use of senior or advanced practitioner in the title.	We have decided to include this recommendation later in our manuscript but have chosen to keep the title the same.
<b>Page 1; Line 42:</b> Were participants recruited nationally, one site, purposive?	We have included more information about the participant selection has been included in the abstract.
<b>P2; L23:</b> "LUS has been shown to be more accurate than chest radiograph..." – can be? When used by who?	We have amended this sentence to add additional clarity and the reviewers recommended phrasing.
<b>P2; L36:</b> Include "or undergraduate training".	We have included this into the sentence.
<b>P2; L48:</b> Is the greater evidence to support the use of LUS?	The section now includes additional evidence of both the diagnostic accuracy of LUS to identify respiratory pathologies and how this could potentially be applied in and ICU setting to influence clinical reasoning and intervention decision.
<b>P2; L51:</b> <ul style="list-style-type: none"> <li>• Include "senior"</li> <li>• Re-word sentence</li> <li>• Include context of low numbers</li> </ul>	<ul style="list-style-type: none"> <li>• We have included "senior" as an included term.</li> <li>• The sentence has been re-written.</li> <li>• An additional sentence has been added to convey the "trail blazing" nature of this technique for physiotherapy by including national numbers at the time of the interviews taking place.</li> </ul>
<b>P4; L29:</b> Signpost readers to LUS training options.	A new reference has been included which signposts the reader to the LUS training programme being followed by all 8 participants.
<b>P5; L9:</b> Exclusion on data from the pilot interview.	This data was not included as minor amendments were made to some questions to optimise clarification and from a methodological viewpoint, the authors regard this as good practice. It is acknowledged that the inclusion of pilot data in qualitative research is a contentious issue as evidenced by this debate: <a href="https://www.researchgate.net/post/Can-the-sample-used-for-pilot-testing-be-included-in-the-final-research-sample">https://www.researchgate.net/post/Can-the-sample-used-for-pilot-testing-be-included-in-the-final-research-sample</a>
<b>P13; L43:</b> LUS as an adjunct to skills as opposed to adopting? Or both?	This sentence has been re-written to add some clarity.
<b>P16; L8:</b> Physio specific?	This sentence has been re-written with physio specific references included.
<b>P17; L6:</b> Bias relating to the recruitment of participants having attended the lead author's course. More information about how widely the net was cast for participant recruitment.	Some additional clarity for the reasons for all 8 participants having attended a course run by the lead author has been included in the limitations.  Information about the recruitment of potential participants via the national professional network newsletter now includes the newsletters readership which was potentially 1400 at the time of the call out.
<b>P17; L29:</b> Question design	The interview topic guide was generated collaboratively. The key drivers for the topic guide were: 'A topic guide was devised (Appendix 2) to ensure interviews explored key concepts having been informed by issues identified from our previous national survey [6] and the research aims.' The specialist clinical knowledge of one researcher informed the study's research question



1 2 3 4 5 6 7 8	and its main aims but the content of the interview topic guide was predominantly driven by the previous survey's findings. The interviewer's experience in qualitative research and core physiotherapy knowledge informed the structure of the interview and phrasing of the questions. As this researcher did not use LUS in practice, there was no bias or ability to direct participants away from their individual viewpoints. This collaboration driven by specialist knowledge informing the question and independent data collection was considered the most robust approach.
9 10 11	<b>P17; L53:</b> Re-word final sentence of the conclusion. We have taken this comment onboard and re-worded the final sentences of the conclusion.

**Reviewer: 2**

Comments to the Author	Author response
16 17 18 19 20 21 22	16 17 18 19 20 21 22
Include in limitations section that views are only that of 8 physiotherapy LUS enthusiast, not representative of all respiratory physiotherapists.	This point has now been included in the limitations section.

**Associate Editor**

Comments to the Author	Author response
27 28 29 30 31	27 28 29 30 31
Please clarify the content of the 1-day LUS training.	A new reference has been added signposting readers to the full training programme. In addition, a brief description on the 1-day training format has been included in Figure 1.
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46	32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
Who created the questionnaire and how did you manage bias on questions?	The interview topic guide was generated collaboratively. The key drivers for the topic guide were: 'A topic guide was devised (Appendix 2) to ensure interviews explored key concepts having been informed by issues identified from our previous national survey [6] and the research aims.' The specialist clinical knowledge of one researcher informed the study's research question and its main aims but the content of the interview topic guide was predominantly driven by the previous survey's findings. The interviewer's experience in qualitative research and core physiotherapy knowledge informed the structure of the interview and phrasing of the questions. As this researcher did not use LUS in practice, there was no bias or ability to direct participants away from their individual viewpoints. This collaboration driven by specialist knowledge informing the question and independent data collection was considered the most robust approach.