Appendix: Supplementary Online Content

Soni NJ, Franco-Sadud R, Kobaidze K, et al. Recommendations on the use of ultrasound guidance for adult lumbar puncture: a position statement of the Society of Hospital Medicine

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This supplementary material has been provided by the authors to give readers additional information about their work. It was last updated on February 18, 2019.

Appendix 1 – Detailed Methods

Expert Panel Formulation

The Society of Hospital Medicine (SHM) Board of Directors delegated the SHM Education Committee with the task of developing recommendations on the use of ultrasound to guide bedside procedures. The chair of the SHM Education Committee appointed two chairs to lead the guideline development project, a subject matter expert in POCUS, and a senior member of the education committee. An additional subject matter expert co-chair was added given the broad scope of the project.

The SHM POCUS Task Force was assembled to carry out this guideline development project under the direction of the SHM Board of Directors, Director of Education, and Education Committee. All expert panel members were physicians or advanced practice providers with expertise in POCUS. Expert panel members were divided into working group members, external peer reviewers, and a methodologist. All expert panel members and two members of the SHM education committee were voting members. Working group members were required to be hospitalists per the SHM definition (1) and have expertise in POCUS. External peer reviewers were nationally recognized physicians with expertise in POCUS from different specialties, including emergency medicine, critical care, anesthesiology, pulmonary/critical care, internal medicine, and cardiology. All external peer reviewers had to have past experience in developing point-of-care ultrasound guidelines, either serving as a chair or member of a guideline development panel. A methodologist with clinical expertise in POCUS and past experience in leading development of POCUS guidelines served on the expert panel. Non-voting Task Force members included a medical librarian, the SHM Education Committee Chair, and the SHM Director of Education (see Acknowledgements).

Disclosures

This project did not receive any funding from any external sponsors or SHM. All Task Force members voluntarily participated, and none received an honorarium for participation. There was no industry input in the development of these guidelines, nor industry presence during any conference calls or meetings. All SHM POCUS Task Force members were required to disclose any potential conflicts of interests. Signed disclosure

statements of all members were reviewed by the SHM Director of Education and an SHM POCUS Task Force chair prior to inclusion on the Task Force. None of the lumbar puncture working group members reported any financial relationships. Two working group members (not in the lumbar puncture working group), three external peer reviewers, and one of the chairs reported financial relationships. Decisions to approve participation were guided by the 2008 and 2011 Institute of Medicine (IOM) reports on development of trustworthy Clinical Practice Guidelines (2,3). Prior to submission of this manuscript, all Task Force members were required to submit an updated conflict of interest disclosure statement for inclusion as an author or collaborator on the final manuscript. Conflict of Interest disclosures are included in Appendix 2.

Literature Search Strategy

The literature search was conducted in two independent phases. The first phase included independent literature searches conducted by working group members themselves. Each lumbar puncture working group member and one co-chair independently performed literature searches to avoid selection bias. Potentially relevant references were compiled, discussed during conferences calls every 2-4 weeks, and selected references were summarized in a shared, online data table. Based on the references gathered during the first phase of literature searches, key clinical questions and draft recommendations were prepared prior to conducting a systematic literature search. The purpose of the first phase literature search was to identify key topics to focus the systematic literature search performed by the certified medical librarian.

The second phase was a systematic literature search conducted by a certified medical librarian based on the draft recommendation prepared by the lumbar puncture working group. The Medline, Embase, CINAHL, and Cochrane medical databases were searched from 1975 to October 2015 initially. Updated searches were conducted in November 2016, January 2018, and October 2018. Search limiters were English language and adults only. Google Scholar was also searched without any limiters. Search terms and specific search strings are shown in Appendix 3. Articles identified by the comprehensive literature search were systematically screened and selected. All article abstracts were first screened for relevance by at least two members of the lumbar puncture working group. Full-text versions of screened articles were reviewed, and articles on the use of ultrasound to guide lumbar puncture were selected. Articles that discussed lumbar puncture without ultrasound guidance or performance on non-human tissues were excluded. Additionally, the following article

types were excluded: non-English language, non-human, age<18, meeting abstracts, meeting posters, letters, case reports, and editorials. All systematic reviews, meta-analyses, randomized controlled trials, and observational studies of ultrasound-guided lumbar puncture were screened and selected. References listed in narrative review articles were reviewed to ensure no important studies were missed. All full text articles were shared electronically amongst the working group members. Any disagreements about article selection were discussed during conference calls and final selection was based on consensus of the lumbar puncture working group. Findings from the selected articles were abstracted into a data table. The selected literature was incorporated into the rationales of the draft recommendations during a series of weekly conference calls.

Development of Clinical Recommendations and Consensus

These recommendations were developed using the RAND Appropriateness Method that required panel judgment and consensus. Details about the RAND Appropriateness Method to gather consensus have been previously published (4). Voting members of the SHM POCUS Task Force reviewed and voted on the draft recommendations using the RAND appropriateness method. Panel members were advised to vote on appropriateness based on these 5 transforming factors: 1) Problem priority and importance, 2) Level of quality of evidence, 3) Benefit / harm balance, 4) Benefit / burden balance, 5) Certainty / concerns about PEAF (Preferences / Equity Acceptability / Feasibility).

The draft recommendations were uploaded into an internet-based electronic data collection tool (REDCap™) (Appendix 4). An invitation email was sent to panel members that included a link to vote and the data table with hyperlinks to view full-text PDF's of the reference articles. Panel members participated in two rounds of electronic voting in February 2018 and April 2018. Voting was conducted using a 9-point Likert scale, where 1 denotes extremely inappropriate and 9 denotes extremely appropriate with three zones: 1–3 points = inappropriate zone; 4–6 points = uncertain zone; and 7–9 points = appropriate zone. Based on the feedback from the first round of voting, minor modifications were made to the draft recommendations classified as having "disagreement." The RAND appropriateness method was applied using expert consensus for recommendations. The degree of consensus was assessed using the RAND algorithm during the 2 rounds of voting (see below, Figure 1). Establishing a recommendation required at least 70% agreement that a recommendation was "appropriate." A strong recommendation required at least 80% of the votes within one

integer of the median, following the RAND rules (see below, Table 1). Disagreement was defined as >30% of panelists voting outside of the zone of the median.

The Lumbar Puncture Working Group members reviewed the voting results and narrative comments, to revise the draft recommendations. Any recommendations with disagreement were removed. Some phrases and references from recommendations with disagreement were incorporated in relevant recommendations without disagreement, or added to the Knowledge Gaps section. Recommendations were classified as strong or weak/conditional based on preset rules defining the panel's level of consensus, which determined the wording for each recommendation (see below, Table 2). For strong recommendations, the phrase ''we recommend'' was used, along with the verb ''must'' or ''should'' depending upon whether or not the degree of consensus was perfect vs. very good, respectively. For weak or conditional recommendations, the phrase ''we suggest'' was used, along with the verb "can" or ''may'' depending on whether or not there was "good" vs. "some" consensus, respectively (4).

The final recommendations were reviewed and revised by a writing committee, which consisted of the Lumbar Puncture Working Group, chairs of all 5 working groups, and 2 of the Task Force co-chairs. The writing group was tasked with final review of each recommendation's wording, clinical relevance, usability, and feasibility. The revised manuscript underwent external peer review by POCUS experts from different subspecialties that are members of SHM POCUS Task Force. Final review of this position statement was performed by all members of the SHM POCUS Task Force, SHM Education Committee, and SHM Executive Committee. The SHM Executive Committee endorsed this position statement in June of 2018 prior to submission to the Journal of Hospital Medicine .

Figure 1 – RAND Algorithm

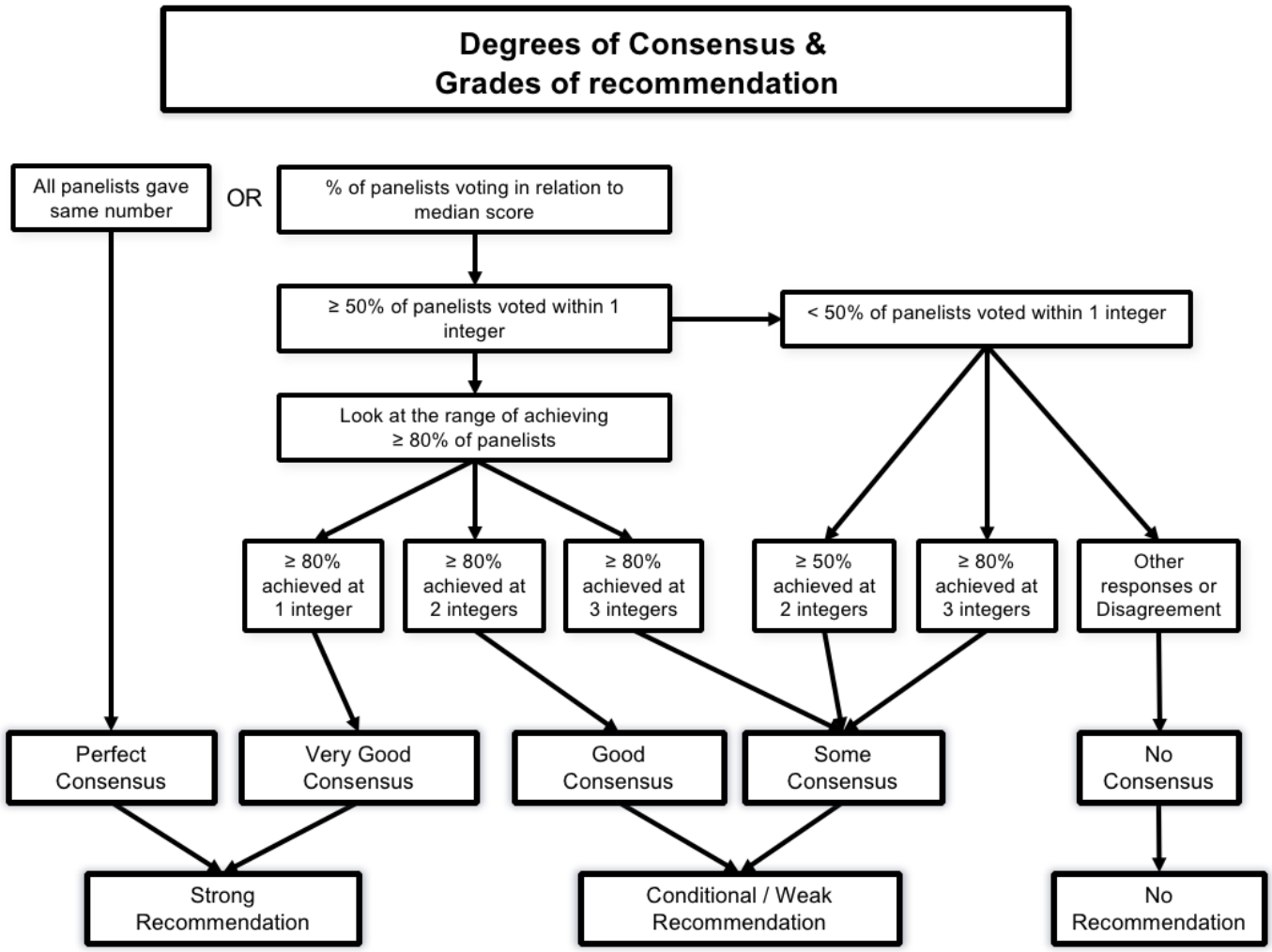


Table 1 – Definitions of Levels of Consensus

Term	Definition
Perfect consensus	All respondents agree on one number between 7-9
Very good consensus	Median and middle 50% (interquartile range) of respondents are found at one integer (*e.g.*, median and interquartile range are both at 8) or 80% of respondents are within one integer of the median (*e.g.*, median is 8, 80% respondents are from 7 to 9)
Good consensus	50% of respondents are within one integer of the median (*e.g.*, median is 8, 50% of respondents are from 7 to 9) or 80% of the respondents are within two integers of the median (*e.g.*, median is 7, 80% of respondents are from 5 to 9).
Some consensus	50% or respondents are within two integers of the median (*e.g.*, median is 7, 50% of respondents are from 5 to 9) or 80% of respondents are within three integers of the median (*e.g.*, median is 6, 80% of respondents are from 3 to 9).
No consensus	All other responses. Any median with disagreement

Table 2 – Degree of Consensus, Strength of recommendation, and Wording

Degree of consensus	Strength of recommendation	Wording [Function of voting]
Perfect consensus	Strong	recommend – must/to be/will
Very good consensus	Strong	recommend – should be/can
Good consensus	Weak/Conditional	suggest – to do
Some consensus	Weak/Conditional	suggest - may do
No consensus Disagreement	NO	No recommendation was made regarding

References

1. Definition of hospitalist available at: https://www.hospitalmedicine.org. Accessed May 15, 2015.

2. (IOM) IoM. Clinical Practice Guidelines We Can Trust. Washington, DC: The National Academies Press, 2011.

3. (IOM) IoM. Knowing What Works in Health Care: A Roadmap for the Nation. Washington, DC2008.

4. Fitch, Kathryn, Steven J. Bernstein, Maria Dolores Aguilar, Bernard Burnand, Juan Ramon LaCalle, Pablo Lazaro, Mirjam van het Loo, Joseph McDonnell, Janneke Vader and James P. Kahan. The RAND/UCLA Appropriateness Method User's Manual. Santa Monica, CA: RAND Corporation, 2001. http://www.rand.org/pubs/monograph_reports/MR1269.html.

Appendix 2 – Conflict of Interest Disclosures of SHM Point-of-care Ultrasound Task Force

Task Force Member	Disclosure	Company	Relationship	Related to project
Chairs				
Jeff Bates	No	--	--	--
Ricardo Franco	No	--	--	--
Nilam Soni	Yes	Elsevier-Saunders	Royalty	No
Working Group Members				
Saaid Abdel-Ghani	No	--	--	--
Anjali Bhagra	No	--	--	--
Carolina Candotti	No	--	--	--
Joel Cho	No	--	--	--
Ria Dancel	No	--	--	--
Trevor Jensen	No	--	--	--
Venkat Kalidindi	No	--	--	--
Ketino Kobaidze	No	--	--	--
Josh Lenchus	No	--	--	--
Brian Lucas	No	--	--	--
Benji Matthews	No	--	--	--
Martin Perez	No	--	--	--
Nitin Puri	Yes	Fujifilm-Sonosite	Honorarium	No
Kreegan Reierson	No	--	--	--
Sophia Rodgers	Yes	NCNP	Honorarium	No
Gerard Salame	No	--	--	--
Dan Schnobrich	No	--	--	--
David Tierney	No	--	--	--
Peer Reviewers				
Robert Arntfield	Yes	Fujifilm-Sonosite Elsevier-Saunders	Honorarium Royalty	No No
Michael Blaivis	No	--	--	--
Richard Hoppmann	Yes	Echonous	Advisory Board	No
Paul Mayo	No	--	--	--
Vicki Noble	Yes	Cambridge University Press	Royalty	No
Aliaksei Pustavoitau	No	--	--	--
Kirk Spencer	No	--	--	--
Vivek Tayal	No	--	--	--
Methodologist				
Mahmoud El-Barbary	No	--	--	--
Medical Librarian				
Loretta Grikis	No	--	--	--
SHM Education Committee				
Daniel Brotman	No	--	--	--
Susan Hunt	No	--	--	--
Satyen Nichani	No	--	--	--
SHM Staff				
Nick Marzano	No	--	--	--

Appendix 3 – Lumbar Puncture Literature Search Strings

A comprehensive literature search was performed of the following databases: Medline, Embase, CINAHL, and Cochrane. The following article types were excluded: non-English language, non-human, age<18, conference abstracts and posters, letters, narrative reviews, case reports, editorials, spinal nerve root injections, regional anesthesia, and assessment of lumbar spine anatomy alone. All relevant systematic reviews, meta-analyses, randomized controlled trials, and observational studies were included. Search strings for each database are listed below.

Lumbar Puncture Clinical Outcomes and Technique Search Strings:

- **PubMed:** ("Spinal Puncture"[Mesh] OR "lumbar puncture"[tiab] OR "spinal tap"[tiab] OR "spinal block"[tiab] OR "spinal anesthesia"[tiab] OR "spinal anaesthesia"[tiab] OR "caudal block"[tiab] OR "epidural anesthesia"[tiab] OR "epidural anaesthesia"[tiab] OR "epidural injection"[tiab] OR "Anesthesia, Spinal"[Mesh] OR "Injections, Spinal"[Mesh] OR "Anesthesia, Epidural"[Mesh]) OR "Injections, Epidural"[Mesh]) AND ("Ultrasonography"[Mesh] OR ultrasound[tiab] OR "Radiography"[Mesh] OR imaging [tiab] OR sonograph*[tiab] OR echograph*[tiab] OR Doppler[tiab] OR echocardiograph*[tiab] OR ultrasonic[tiab])

- **Embase:**
  - ('lumbar puncture'/exp OR 'lumbar puncture':ti OR 'spinal puncture':ti OR 'spinal tap':ti OR 'spinal block':ti OR 'spinal anesthesia'/exp OR 'spinal anesthesia':ti OR 'spinal anaesthesia':ti OR 'caudal anesthesia'/exp OR 'epidural anesthesia':ti OR 'epidural anaesthesia':ti OR 'epidural injection':ti OR 'intraspinal drug administration'/exp OR 'epidural anesthesia'/exp OR 'epidural injections':ti OR 'spinal injections':ti) AND ('ultrasound'/exp OR ultrasonography:ti OR ultrasound:ti OR radiography:ti OR 'imaging'/exp OR sonograph*:ti OR echograph*:ti OR doppler:ti OR echocardiography*:ti OR ultrasonic:ti)
  - Limiters—Embase only/ages from Young Adult on

- **CINAHL:**
  - (MH "Spinal Puncture"OR MH "Anesthesia, Spinal" OR MH "Anesthesia, Epidural" OR MH "Injections, Epidural" OR "lumbar puncture"(ti) OR "spinal puncture"(ti) OR "spinal tap"(ti) OR "spinal block"(ti) OR "caudal anesthesia"(ti) OR "caudal anaesthesia"(ti) OR "caudal block"(ti) OR "epidural injection"(ti) OR "spinal injection"(ti)) AND (MH "Ultrasound" OR ultrasonography(ti) OR ultrasound(ti) OR radiography(ti) OR imaging(ti) OR echography(ti) OR sonography(ti) OR echocardiograph*(ti) OR ultrasonic (ti))
  - Limiters—Exclude Medline/PubMed Records

- **Cochrane:** ("spinal Puncture" OR "lumbar puncture" OR "spinal tap" OR "spinal block" OR "spinal anesthesia" OR "spinal anaesthesia" OR "caudal block"OR "epidural anesthesia" OR "epidural anaesthesia" OR "epidural injection" OR "spinal anesthesia" OR "spinal injections" OR "epidural injections") AND (Ultrasonography OR Radiography OR ultrasound OR imaging OR sonograph* OR echograph* OR Doppler OR echocardiograph* OR ultrasonic):ti,ab,kw (Word variations have been searched)

- **Google Scholar:** ("spinal Puncture"OR "lumbar puncture" OR "spinal tap" OR "spinal block" OR "spinal anesthesia" OR "spinal anaesthesia" OR "caudal block" OR "epidural anesthesia" OR "epidural anaesthesia" OR "epidural injection" OR "spinal anesthesia" OR "spinal injections" OR "epidural injections") AND (Ultrasonography OR Radiography OR ultrasound OR imaging OR sonograph* OR echograph* OR Doppler OR echocardiograph* OR ultrasonic)

Lumbar Puncture Training Search Strings:

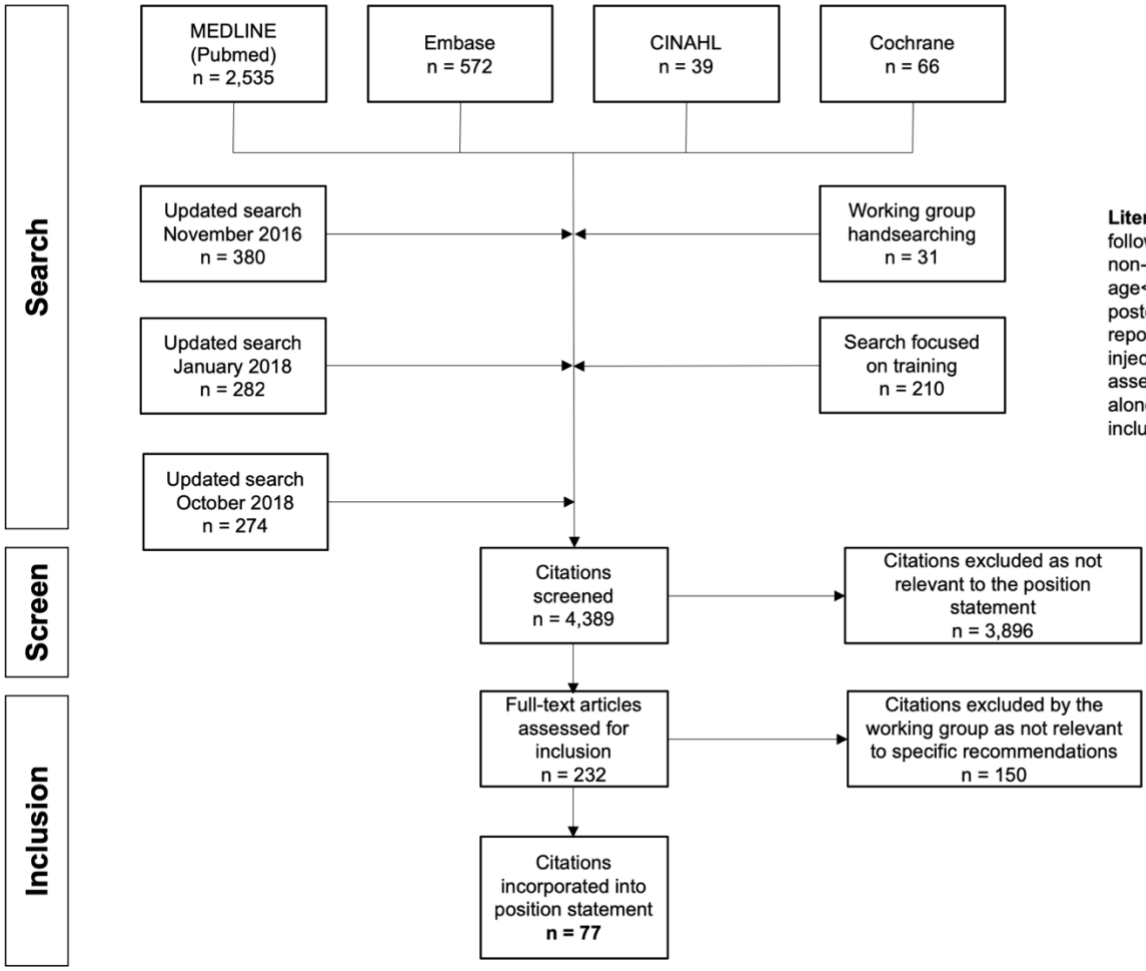
- **PubMed:** ("Spinal Puncture"[Mesh] OR "lumbar puncture"[tiab] OR "spinal tap"[tiab] OR "spinal block"[tiab] OR "spinal anesthesia"[tiab] OR "spinal anaesthesia"[tiab] OR "caudal block"[tiab] OR "epidural anesthesia"[tiab] OR "epidural anaesthesia"[tiab] OR "epidural injection"[tiab] OR "Anesthesia, Spinal"[Mesh] OR "Injections, Spinal"[Mesh] OR "Anesthesia, Epidural"[Mesh]) OR "Injections, Epidural"[Mesh]) AND ("Ultrasonography"[Mesh] OR ultrasound[tiab] OR "Radiography"[Mesh] OR imaging [tiab] OR sonograph*[tiab] OR echograph*[tiab] OR Doppler[tiab] OR echocardiograph*[tiab] OR ultrasonic[tiab]) AND (competent[ti] OR competence[ti] OR competency[ti] OR competencies [ti] OR simulat*[ti] OR train*[ti] OR educat*[ti] OR technique*[ti] OR skill*[ti] OR method*[ti] OR teach*[ti] OR learn*[ti])

- **Embase:** ('lumbar puncture'/mj OR 'lumbar puncture':ti OR 'spinal puncture':ti OR 'spinal tap':ti OR 'spinal block':ab OR 'spinal block':ti OR 'spinal anesthesia'/exp OR 'spinal anesthesia':ti OR 'spinal anaesthesia':ti OR 'caudal anesthesia'/exp OR 'epidural anesthesia':ti OR 'epidural injection':ti OR 'intraspinal drug administration'/mj OR 'epidural anesthesia'/mj OR 'spinal injections':ti) AND ('ultrasound'/mj OR ultrasonography:ti OR ultrasound:ti OR 'imaging'/mj OR sonograph*:ti OR echograph*:ti OR doppler:ti OR echocardiography*:ti OR ultrasonic:ti) AND (competent:ti OR competence:ti OR competency:ti OR competencies:ti OR simulat*:ti OR train*:ti OR educat*:ti OR technique*:ti OR skill*:ti OR method*:ti OR teach*:ti OR learn*:ti)

- **CINAHL:** ((MH "Spinal Puncture") OR (MH "Anesthesia, Spinal") OR (MH "Anesthesia, Epidural") OR (MH "Injections, Epidural") OR "lumbar puncture" OR "spinal puncture" OR "spinal tap" OR "spinal block" OR "caudal anesthesia" OR "caudal block" OR "epidural injection" OR "spinal injection") AND ((MH "Ultrasound") OR ultrasonography OR ultrasound OR radiography OR imaging OR echography OR sonography OR Doppler OR echocardiograph* OR ultrasonic) AND (competent OR competence OR competency OR competencies OR simulat* OR train* OR educat* OR technique* OR skill* OR method* OR teach* OR learn*)

- **Cochrane:** ("lumbar puncture" OR "spinal puncture" OR "lumbar puncture" OR "spinal tap" OR "spinal block" OR "caudal anesthesia" OR "caudal block" OR "epidural injection" OR "spinal injection") AND (ultrasonography OR ultrasound OR radiography OR imaging OR echography OR sonography OR Doppler OR echocardiograph* OR ultrasonic) AND (competent OR competence OR competency OR competencies OR simulat* OR train* OR educat* OR technique* OR skill* OR method* OR teach* OR learn*)

Figure 1 – Literature search strategy



Literature Selection Strategy: The following article types were excluded: non-English language, non-human, age<18, conference abstracts and posters, letters, narrative reviews, case reports, editorials, spinal nerve root injections, regional anesthesia, and assessment of lumbar spine anatomy alone. See appendix 3 for terms included in literature search.

Appendix 4 - Lumbar Puncture Recommendations - SHM POCUS Guidelines - Round 2 Voting

Instructions: Please rate your level of agreement with each of the recommendations on the use of ultrasound to guide lumbar puncture. A detailed literature review is provided in the "Comment" box.

We have included background information on the RAND Appropriateness Method below. It is NOT required that you read about RAND RAM before proceeding.

Introduction to RAND Appropriatenss Method (RAM)

RAM provides a structured method to obtain feedback regarding ranking or agreement of a statement or clinical procedure. RAND corporation, in conjunction with UCLA developed this method to evaluate scientific evidence and expert opinion in health care procedures and best practice guidelines. This method has become a leading standard for quality assessment in medicine. More information about the RAND Appropriateness Method, its uses and how it was developed can be found at:

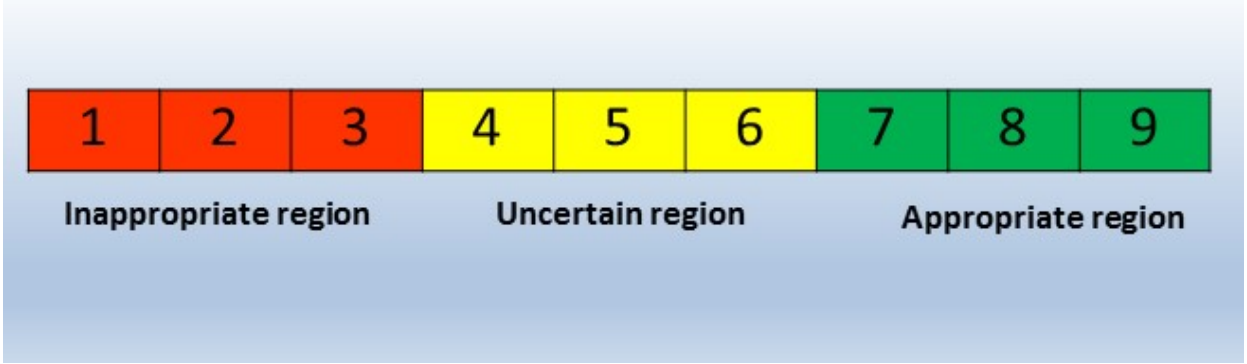
RAND/UCLA Appropriateness Method User's Manual

RAND Rules for Voting

Recommendation Ranking Instructions

Please rank the recommendations according to the RAND Appropriateness Scale.

1 = Extremely Inappropriate vs. 9 = Extremely Appropriate



When voting please consider the 5 transforming factors with stronger recommendations fulfilling more of these factors.

5 Transforming Factors:

1) Problem Priority / Importance - How critical is the potential outcome of this recommendation?
2) Level of Quality of Evidence (LQE) - How high is the Level of Quality of Evidence?
3) Benefit / Harm balance - How large is the net benefit/harm of the outcome of the recommendation?
4) Benefit / Burden balance - Is the burden worth the benefit?
5) Certainty / Concerns about PEAF (Preferences / Equity Acceptability / Feasibility) - How certain are you this recommendation would be feasible, equitable, acceptable, and preferred by patients?

[Attachment: "RAND EtD table.pdf"]

Last Name:

_____

First Name:

_____

Recommendations on the Use of Ultrasound Guidance for Adult Lumbar Puncture

A Position Statement by the Society of Hospital Medicine

Terminology:

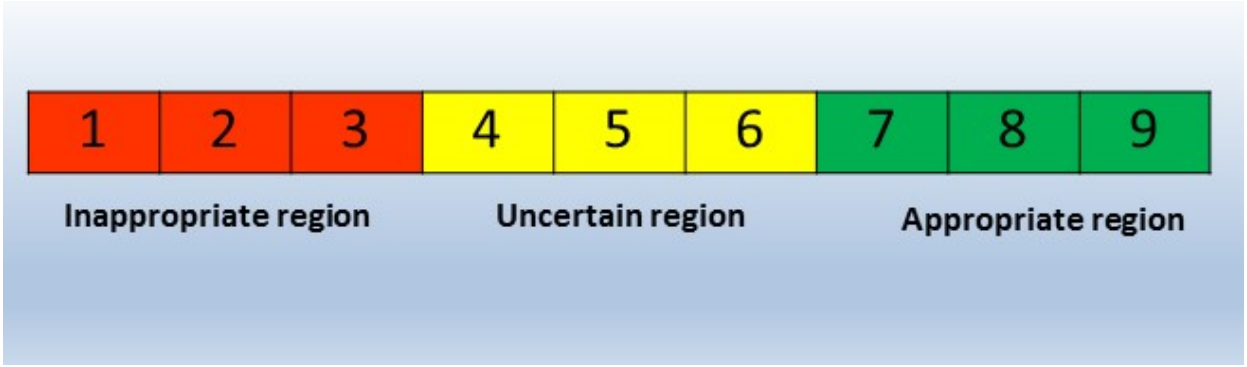
● Lumbar puncture (LP) is a procedure in which a spinal needle is introduced into the subarachnoid space for the purpose of collecting cerebrospinal fluid (CSF) for diagnostic evaluation and/or therapeutic drainage.

● Throughout this document, the phrases "ultrasound-guided" or "ultrasound guidance" refer to use of ultrasound to mark a needle insertion site immediately before performing the procedure. This is also called static ultrasound guidance. Real-time or dynamic ultrasound guidance refers to direct visualization of the needle tip as it traverses through the skin and soft tissues to reach the ligamentum flavum. Any reference to real-time ultrasound guidance will be explicitly stated.

Please add any comments:

Clinical Outcomes

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

1) Use ultrasound guidance for site selection of lumbar puncture to reduce the number of needle insertion attempts and needle redirections, and increase overall procedure success rates, with the greatest benefit demonstrated in obese patients. (Round 1 Voting: Weak recommendation with good consensus = "SUGGEST use...")
(Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Lumbar puncture has historically been performed by selecting a needle insertion site based on palpation of anatomical landmarks. However, an estimated 30% of emergency department (ED) patients requiring lumbar puncture have difficult to palpate lumbar spine landmarks, most commonly due to obesity.(1) Ultrasound can be used at the bedside to elucidate the lumbar spine anatomy to guide performance of lumbar puncture or epidural catheterization. Randomized studies comparing use of ultrasound guidance (ultrasound-guided) versus anatomical landmarks (landmark-guided) to map the lumbar spine for epidural catheterization began to emerge in the early 2000's. It is important to note that the same technique is used to mark a needle insertion site with ultrasound or landmarks for lumbar puncture, epidural catheterization, and spinal anesthesia, and therefore, data from these studies is often pooled. Currently, at least 29 randomized controlled studies comparing ultrasound-guided vs. landmark-guided site selection for lumbar puncture, epidural catheterization, or spinal anesthesia have been published.(2-25)

Shaikh et al published a meta-analysis in 2013 that included 14 randomized controlled studies comparing ultrasound-guided vs. landmark-guided site selection for lumbar puncture (n=5) or epidural catheterization (n=9). The pooled data showed that use of ultrasound guidance decreased rates of failed procedures [risk ratio 0.21 (95% CI 0.10 to 0.43), p< 0.001) with an absolute risk reduction of 0.063 (95% CI 0.041 to 0.084) and a number needed to treat to prevent one failed procedure of 16 (95% CI 12 to 25). Also, use of ultrasound reduced the number of attempts [mean difference -0.44 (-0.64 to -0.24), p< 0.001] and number of needle redirections [mean difference −1.00 (-1.24 to -0.75), p< 0.001]. Reduction in rates of failed procedures was similar for lumbar punctures [risk ratio 0.19 (95% CI 0.07 to 0.56), p=0.002] and epidural catheterizations [risk ratio 0.23 (95% CI 0.09 to 0.60), P=0.003].(26)

At least 15 randomized controlled studies have been published since the meta-analysis by Shaikh et al, and these more recent studies demonstrate similar benefits of using ultrasound guidance: reduced needle insertion attempts, reduced needle redirections, and increased overall procedure success rates. Use of ultrasound was compared to use of landmarks alone to perform lumbar puncture in 2 studies(13,27) and spinal anesthesia or epidural catheterization in 13 studies.(2,3,11,14,15,17,19-21,23-25,28)

Four randomized controlled studies did not demonstrate any benefits of using ultrasound guidance versus landmarks for site selection. Limitations of these negative studies include potential selection bias and inadequate sample sizes, and varying levels of operator skills in procedures, ultrasound, or both. One study included emergency medicine residents as operators with varying degrees of ultrasound experience, and more importantly, patient enrollment occurred by convenience sampling which may have introduced selection bias. Additionally, most patients were not obese (median BMI of 27 kg/m2), and it is unclear why 10 years lapsed from data collection until publication.(13) Another study with three experienced anesthesiologists as operators performing spinal anesthesia enrolled only patients with easy to palpate bony landmarks that were not obese (mean BMI of 29 kg/m2) - two patient characteristics associated with the greatest benefit of using ultrasound guidance in other studies.(3) Another negative study had one experienced anesthesiologist marking obstetric patients with ultrasound, but a junior resident that had palpated the spinal landmarks performed the actual procedure in the absence of the anesthesiologist that had marked the patient.(21)

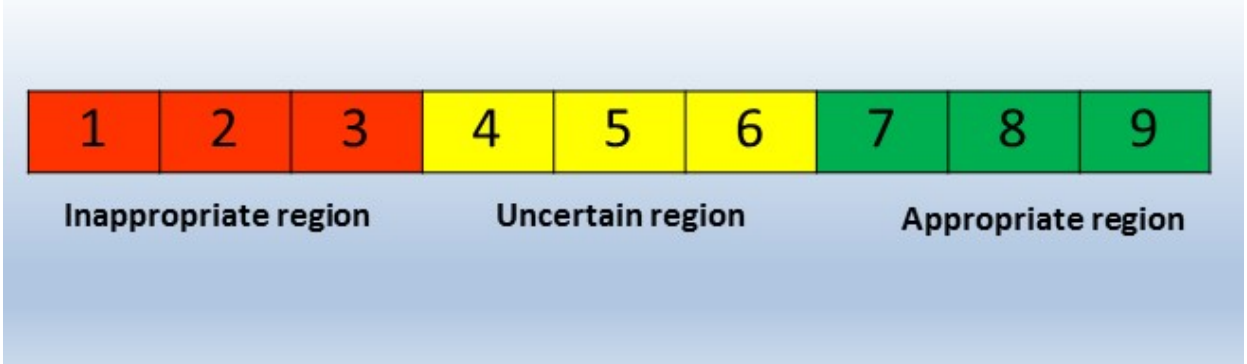
A recent meta-analysis published by Perlas et al in 2016 included a total of 31 randomized controlled studies and cohort studies evaluating the use of ultrasound guidance for lumbar puncture, spinal anesthesia, and epidural catheterization.(29) Three of the 4 negative randomized controlled trials mentioned above were included. The goal of this systematic review and meta-analysis was to establish clinical practice recommendations. The authors concluded: 1) ultrasound increases the efficacy of lumbar epidural or spinal anesthesia by decreasing the number of needle insertion attempts (−0.86; 95% CI, −1.12 to −0.60) and reducing the risk of a failed procedure (combined risk ratio, 0.51; 95% CI, 0.32-0.80), both in patients with normal and technically difficult surface anatomy due to obesity, scoliosis, or previous spine surgery (Grade A recommendation, level of evidence IA); 2) ultrasound allows accurate measurement of the needle insertion depth to reach the epidural space (Grade A recommendation, level of evidence IA); 3) the data consistently suggest that ultrasound is more accurate than palpation for lumbar interspace identification (Grade B recommendation, level of evidence IIA); 4) use of ultrasound may improve safety of neuraxial anesthesia (Grade B recommendation, level of evidence III).

In general, the greatest benefit of using ultrasound guidance for lumbar puncture has been shown in randomized and observational studies with obese patients.(4,12,14,15,30,31) Benefits have been shown in specific obese patient populations, including obstetric,(11,32,33) orthopedic,(4,34,35) and emergency department patients.(27)

The effect of using ultrasound guidance on total procedure time during lumbar puncture, epidural catheterization, or spinal anesthesia is uncertain. Some studies have demonstrated a reduction in total procedure time,(15,22,27,34) while other studies have shown no difference(3,8,12,13,23,24) or an increase in total procedure time(7,19). Regardless of the effect on procedure time, we believe the benefits of ultrasound in reducing the number of needle insertion attempts and increasing the overall procedure success rates likely outweigh any negative effect on the total procedure time.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

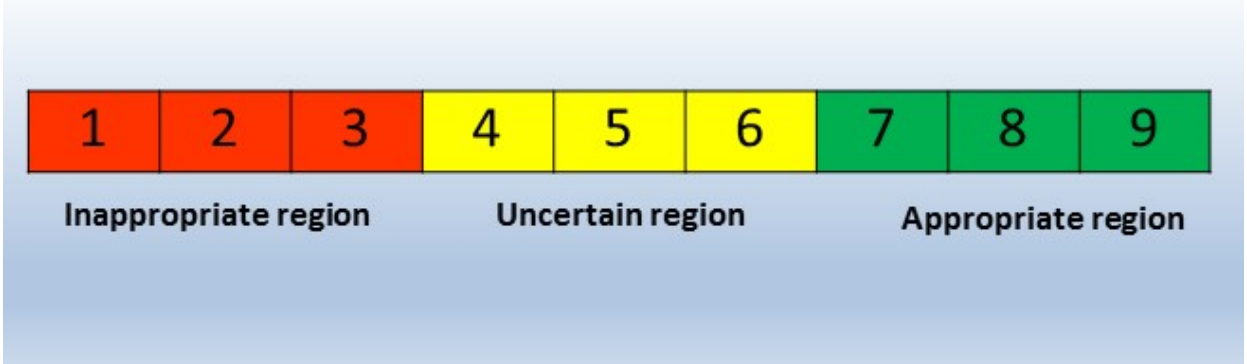
2) Use ultrasound guidance for lumbar puncture to reduce post-procedure back pain and improve patient satisfaction with the greatest benefit shown in overweight or obese patients. (Round 1 Voting: Disagreement with no consensus = No recommendation can be made)
(Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Ultrasound-guided lumbar puncture has been shown to reduce post-procedure back pain and improve patient satisfaction scores compared to a landmark-based approach. The greatest benefit has been demonstrated in patients that are overweight or obese, or have other anatomical limitations (2,8,17,27,28,30). Honarbakhsh et al reported that patients with factors making lumbar puncture difficult (BMI>30, scoliosis, or prior lumbar spine surgery) had back pain rates that were significantly lower with ultrasound-guided versus landmark-based lumbar puncture (8.3% ultrasound-guided vs. 53.8% landmark-based lumbar puncture; p=0.02).(30) Mofidi et al showed that patients who underwent ultrasound-guided LP reported lower pain scores (4.4 ± 1.4 vs. 7.4 ± 1.1, P = 0.001).(27) Similarly, Lim et al reported in a randomized study that significantly more patients reported being "very satisfied" [51% vs. 17% (p=0.0001)] when ultrasound guidance was used for spinal anesthesia.(28) Three randomized trials with operators of varying degrees of experience found no difference in patient satisfaction scores with routine use of ultrasound guidance for lumbar puncture (3,13,20). Two studies have shown a reduction in post-procedure headache after spinal anesthesia with use of ultrasound guidance (8), although similar benefit has not been demonstrated in patients undergoing lumbar puncture.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

3) Use ultrasound guidance for lumbar puncture to reduce the risk of a traumatic tap. (Round 1 Voting: Disagreement with no consensus = No recommendation can be made)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

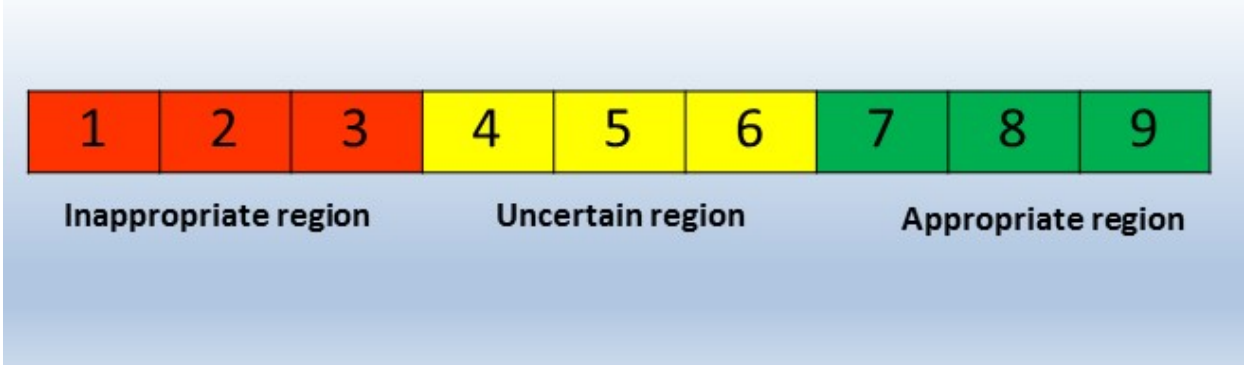
o Comment:
Use of ultrasound guidance to map the lumbar spine has been shown to reduce the frequency of traumatic lumbar punctures (i.e., red blood cells within the cerebrospinal fluid) in both obese and non-obese patient populations. A meta-analysis by Shaikh et al included 5 randomized controlled studies that assessed the effect of ultrasound guidance on traumatic taps. The meta-analysis found a reduced risk of traumatic taps [risk ratio 0.27 (95% CI 0.11 to 0.67), p=0.005], an absolute risk reduction of 5.9% (95% CI 0.023 to 0.095), and a number needed to treat of 17 (95% CI 11 to 44).(26)

A randomized controlled study by Mofidi et al comparing ultrasound-guided (n=40) vs. landmark-guided (n=40) lumbar puncture showed significantly fewer traumatic taps in the ultrasound-guided group (12.5% vs. 45%, p=0.024). A mixed retrospective-prospective case control study of lumbar punctures performed using ultrasound guidance (n=23) versus landmarks alone (n=28) showed no traumatic taps in the ultrasound-guided group vs. 14% in the landmark-guided group, although statistical significance was not reached (p=0.06).

Three randomized trials that did not show any benefits of using ultrasound guidance to improve procedure success rates also did not show any reduction in traumatic lumbar punctures with the use of ultrasound guidance (13,21,28).

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

4) Use ultrasound guidance to select a needle insertion site for lumbar puncture which may reduce patient exposure to ionizing radiation from fluoroscopy. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

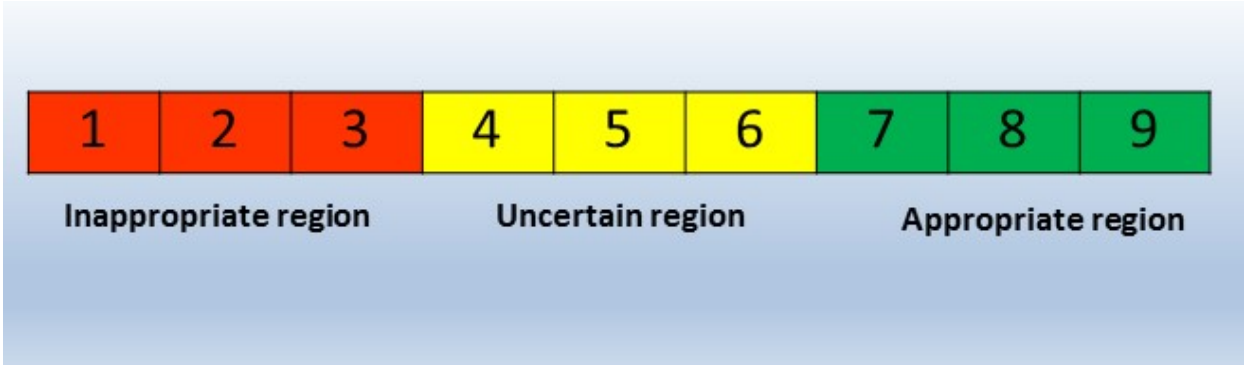
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
As mentioned above, use of ultrasound for site selection of lumbar puncture reduces the number of needle insertion attempts, and increases overall procedure success rates.(26) By increasing the procedure success rates with the use of ultrasound at the bedside, fewer patients may be referred to interventional radiology for fluoroscopic-guided lumbar puncture, decreasing the patient exposure to ionizing radiation. A randomized study (n=112) that compared site marking with ultrasound guidance versus fluoroscopic guidance for epidural steroid injections found no significant difference in the mean procedure time, number of needle insertion attempts, or needle passes.(36) Another randomized study comparing ultrasound vs. fluoroscopic guidance found ultrasound was associated a slightly short¬er performance time (16.7±4.8 vs. 18.7±5.0 minutes; P< 0.05).(37)

Please add any comments:

Technique

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

5) Ultrasound mapping of the lumbar spine can be performed in either a lateral decubitus or sitting position. (Round 1 Voting: Disagreement with no consensus = No recommendation can be made)

(Please use the Appropriateness Scale above to select your recommendation)

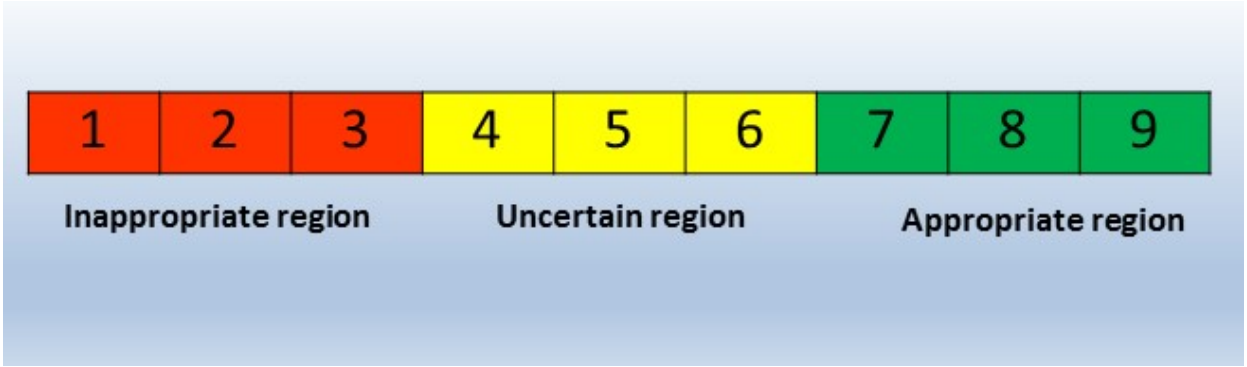
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Ultrasound mapping of the lumbar spine can be performed in either a lateral decubitus or sitting position, and the patient should remain in the same position after selecting and marking a needle insertion site. Lumbar puncture performed in a lateral decubitus position has the advantage of accurately measuring opening pressure. However, misalignment of the shoulder and pelvic girdle, and bowing of the bed, in a lateral decubitus position may lower lumbar puncture success rates.

One randomized study comparing ultrasound-guided spinal anesthesia in a lateral decubitus versus sitting position found no difference in the number of needle insertion attempts or measurement of the skin-dura distance; however, the needle insertion depth was significantly greater in a lateral decubitus vs. sitting position (6.25 ± 0.92cm vs. 5.52 ± 0.69cm; p=0.002).(38) Procedure success rates of lumbar puncture with ultrasound guidance has not been directly compared in a sitting versus lateral decubitus position, although overall procedure success rates were higher in one study that allowed the operator to choose either sitting or lateral decubitus position.(12)

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

6) Using a sitting position widens the interspinous spaces and may be preferred if measurement of opening pressure is not needed. (Round 1 Voting: Disagreement with no consensus = No recommendation can be made)
(Please use the Appropriateness Scale above to select your recommendation)

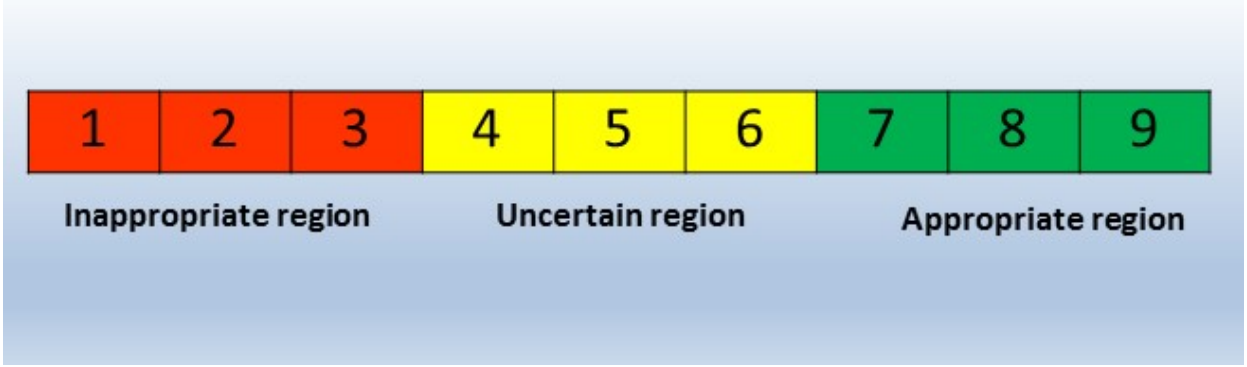
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Although there is limited evidence, a sitting position may ease performance of lumbar puncture by positioning the spine and soft tissues symmetrically, reducing misalignment of the shoulder and pelvic girdles, avoiding bowing of the bed, and subtly widening the interspinous spaces.

A study that used bedside ultrasound to measure interspinous distances demonstrated that a sitting position with the feet supported increased the interspinous space by 0.11cm compared to a lateral decubitus position (mean 1.91 vs. 2.02 cm, p< 0.001). It is important to note that the interspinous distances did not differ if the feet were unsupported in a sitting position compared to a lateral decubitus position.(39) Another study showed that the needle insertion depth from the skin surface to the dura was 0.73 cm less in a sitting position compared to lateral decubitus position. However, there was no significant difference in number of needle insertion attempts or success rates between a sitting and lateral decubitus position in this study.(38) Measurement of the cerebrospinal fluid opening pressure is conventionally performed from a lateral decubitus position, since a sitting position likely overestimates the actual opening pressure. The differential in opening pressure measured in a lateral decubitus position vs. sitting position has not been well studied.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

7) Use ultrasound to more accurately identify the lumbar spine level than physical examination in both obese and non-obese patients. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Traditionally, an imaginary line connecting the iliac crests (intercristal line, Tuffier's line, or Jacobys's line) was considered to identify the L4 vertebra or L4-L5 interspinous space in the midline; however, studies have revealed this traditional landmark to be much less accurate than previously thought. In general, palpating the iliac crests to mark the intercristal line identifies an interspinous space that is one space cephalad (i.e. the L2-L3 interspinous space) but can range from L1-L2 to L4-L5.(40-44) It is important to recall that the spinal cord ends by the level of the L2 vertebral body. If lumbar puncture is inadvertently performed in the L1-L2 interspinous space, the risk of spinal cord injury is higher than if performed in a more distal interspinous space.

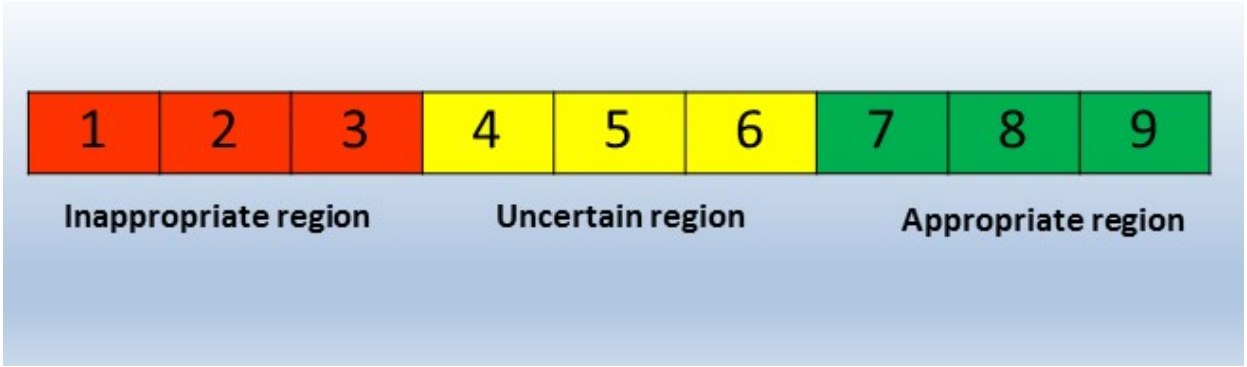
A study by Margarido et al with 45 patients with a mean BMI of 30 kg/ m2 found that the intercristal line was located above the L4-L5 interspinous space in 100% of patients. More importantly, the intercristal line was above L2-L3 in 36% of patients and above L1-L2 in 4% of patients. It is important to note that patients with scoliosis or previous spine surgery were excluded from this study, and all exams were performed by two experienced anesthesiologists with patients in a sitting position - all factors that may have favored accurate palpation and marking of the iliac crests.(40)

In a study of non-obese patients (mean BMI of 28 kg/m2) undergoing spinal anesthesia, Duniec et al compared the lumbar level identified by palpation versus ultrasound and found discordance between the two techniques in 36% of patients - 18% were one space too cephalad, 16% were one space too caudal, and 2% were off by two interspinous spaces.(41) Another study found discordance in 64% of patients (mean BMI of 28 kg/m2) when comparing the interspinous level where spinal anesthesia had been performed by palpation versus a post-procedure ultrasound examination. This study revealed the interspinous space was more cephalad in 50% of patients with 6% of punctures performed in the L1-L2 interspace.(42) A similar study comparing accuracy of palpation vs. ultrasound to identify the L3-L4 interspinous space in obese (mean BMI of 34 kg/ m2) and non-obese (mean BMI of 27 kg/ m2) patients found marking a space above L3-L4 in 51% of obese and 40% of non-obese patients and marking of the L1-L2 interspace in 7% and 4%, respectively.(44)

A study comparing palpation vs. ultrasound found that 68% of obese patients with a BMI >30 had difficult-to-palpate lumbar spine landmarks, but with the use of ultrasound, landmarks were identified in 76% of all patients, including obese and non-obese patients, with difficult-to-palpate landmarks.(45)

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

8) Use a low frequency curvilinear transducer to evaluate the lumbar spine and mark a needle insertion site. A high frequency linear transducer may be used in non-obese patients. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

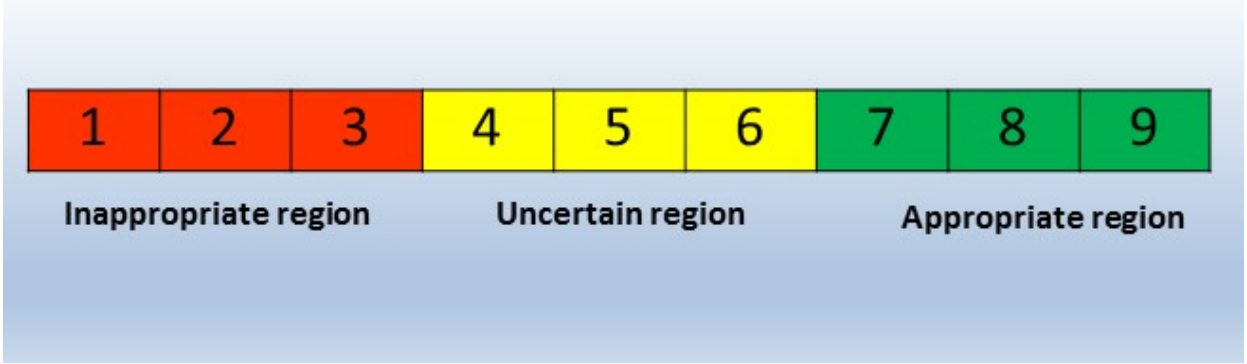
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
The low frequency sound waves of a curvilinear transducer penetrate deep tissues, allowing visualization of the bones and ligaments of the lumbar spine. A high-frequency linear transducer offers better resolution but shallower penetration to a maximum of 6-9cm, limiting its use for site marking in overweight and obese patients. In obese patients, the ligamentum flavum is often deeper than 6cm which requires a low-frequency transducer to be visualized.

Most randomized controlled studies demonstrating benefits of using ultrasound guidance compared to landmark guidance for performance of lumbar puncture, epidural anesthesia, or spinal anesthesia utilized a low-frequency, curvilinear transducer.(2,4,6-8,11,14-16,19,23-25,46) Two randomized controlled trial utilized a high-frequency linear transducer for site marking of lumbar procedures.(12,17,27) Use of a high-frequency linear transducer has been described in real-time ultrasound-guided lumbar procedures, the advantage being better needle visualization with a linear transducer.(9) Detection of blood vessels with color flow Doppler may be another advantage of using a high-frequency linear transducer, although a study by Grau et al showed that use of color flow Doppler with a low-frequency transducer permitted visualization of interspinous vessels as small as 0.5mm in size.(47)

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

9) To map the lumbar spine, start at the level of the sacrum and slide the transducer cephalad, sequentially identifying the lumbar spine interspaces. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

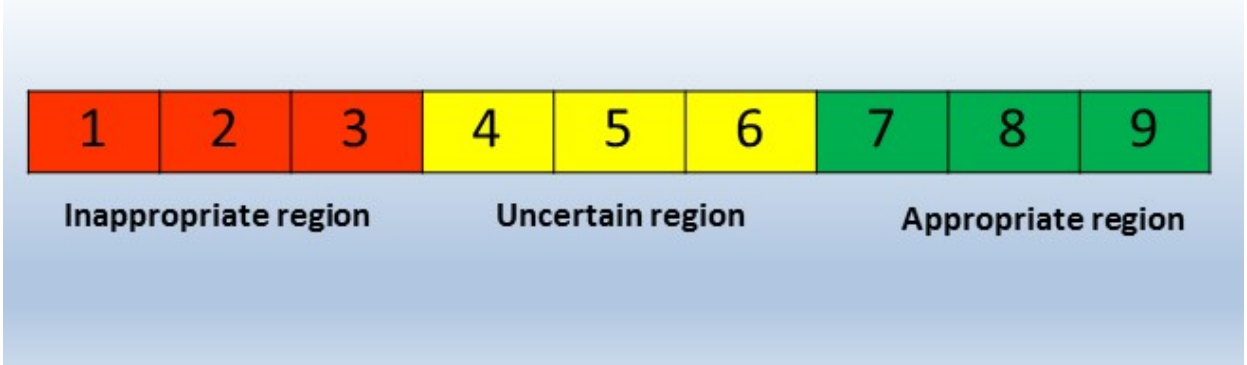
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Although no studies have directly compared different ultrasound scanning protocols to map the lumbar spine, starting at the level of the sacrum and sliding the transducer cephalad to sequentially identify the lumbar interspinous spaces is the most commonly described technique in studies demonstrating improved clinical outcomes with the use of ultrasound.(4,11,14,17,19,20,25,34,35,46) Because the sacrum can be easily recognized, identifying it first is most beneficial in patients with few or no palpable landmarks.

All five lumbar spinous processes and interspinous spaces can be mapped from the sacrum using either a midline or paramedian approach. In the midline approach, a midline transverse view is obtained by centering the transducer on the sacrum and sliding cephalad from L5 to L1 to identify each spinous process and interspinous space. In a paramedian approach, longitudinal paramedian views are obtained from the L5 - sacrum interspace to the L1 - L2 interspace, and each interspinous space is identified as the transducer is slid cephalad. Both of these approaches are effective for mapping the lumbar spine. Whether or not the entire lumbar spine is mapped, and whether a midline or paramedian approach is utilized, will depend upon the operator's preference.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

10) Use ultrasound in a transverse plane to mark the midline of the lumbar spine and a longitudinal plane to mark the interspinous spaces. The intersection of these two lines marks the needle insertion site. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
The most common technique described in comparative studies of ultrasound vs. landmarks includes visualization of the lumbar spine in two planes: a transverse plane to identify the midline and a longitudinal plane to identify the interspinous spaces. Most randomized controlled studies that demonstrated a reduction in the number of needle insertion attempts and increase in procedure success rates utilized this technique (see Clinical Outcomes).(2,4,8,12,15-17,23,24) Marking the midline and interspinous space(s) for lumbar puncture may be performed in any order, starting with either the transverse or longitudinal plane first.

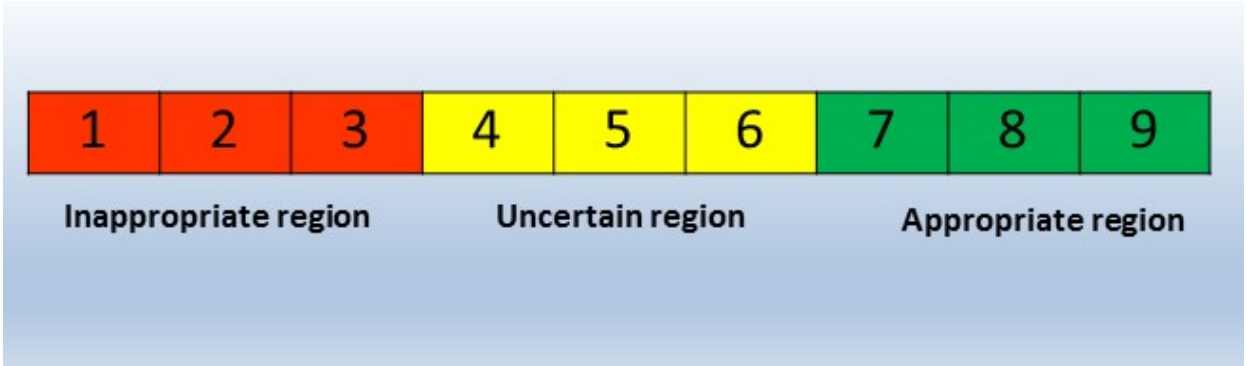
The midline of the spine is marked by placing the transducer in a transverse plane over the lumbar spine, centering over the spinous processes which have a distinct hyperechoic tip and prominent acoustic shadow deep to the bone, and drawing a line perpendicular to the transducer delineating the midline. The midline should be marked over a minimum of two or three spinous processes.

To identify the interspinous spaces, the transducer is aligned longitudinally over the midline. Slide the transducer along the midline to identify the widest interspinous space. Once the transducer is centered over the widest interspinous space, draw a line perpendicular to the transducer to mark the interspinous space. The intersection of the lines marking the spinal midline and interspinous spaces identifies the needle entry point.

To visualize the ligamentum flavum, the transducer is oriented longitudinally over the midline and slid approximately 1cm laterally to obtain a paramedian view of the spine. The skin-ligamentum flavum distance is most reliably measured from a paramedian view. Alternatively, in some patients, the ligamentum flavum may be visualized in the midline and the depth can be measured.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

11) During a pre-procedural ultrasound evaluation, measure the distance from the skin surface to the ligamentum flavum from a longitudinal paramedian view to estimate the needle insertion depth and ensure an adequate length spinal needle is used. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...") (Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
The distance from the skin to ligamentum flavum can be measured using ultrasound during preprocedural planning. Knowing the depth to the ligamentum flavum preprocedurally allows the operator to procure an adequate length spinal needle, anticipate the insertion depth before cerebrospinal fluid can be obtained, determine the depth to which local anesthetic will need to be injected, and decide whether the anticipated difficulty of the procedure warrants referral to or consultation with another specialist.

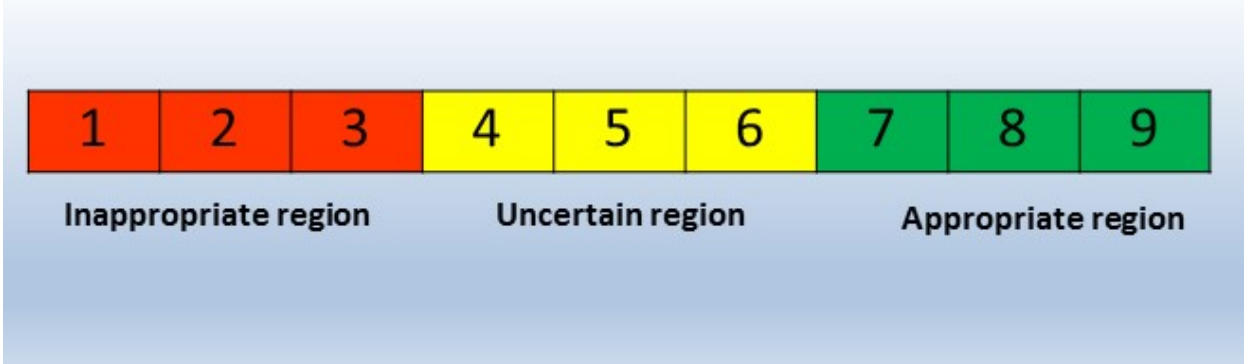
The skin-ligamentum flavum distance can be measured from a transverse midline view or a longitudinal paramedian view. A longitudinal paramedian view provides an unobstructed view of the ligamentum flavum due to less shadowing from bony structures compared to a midline view. Several studies have demonstrated a strong correlation between the skin-ligamentum flavum distance measured by ultrasound and the actual needle insertion depth in both midline and paramedian views.(8,14,16,31,32,35,48)

A meta-analysis that included 13 comparative studies evaluating the correlation between ultrasound-measured depth and actual needle insertion depth required to reach the epidural or intrathecal space.(29) All studies consistently demonstrated a strong correlation between the measured and actual depth with Pearson correlation coefficients ranging from 0.66 to 0.98. A few studies have reported a very strong correlation of 0.98.(33,49,50) The pooled Pearson product moment correlation coefficient was 0.91 (95% CI, 0.87-0.94). All studies measured the depth from the skin to the ventral side of the ligamentum flavum or intrathecal space from either a longitudinal paramedian view (n=4) or a transverse midline view (n=9). Eight of the more recent studies evaluated the accuracy of the ultrasound measurements and found the depth measurements by ultrasound to be accurate within 1 to 13mm of the actual needle insertion depth, with 7 of 8 studies reporting a mean difference of □3mm. This meta-analysis concluded that level 1A evidence exists to make a Grade A recommendation to use ultrasound to predict needle insertion depths to reach the epidural or intrathecal space.(29)

Measurement of the skin - ligamentum flavum distance generally underestimates the needle insertion depth. One study showed measurement of the skin-ligamentum flavum distance underestimates the needle insertion depth by 7.6mm to obtain CSF, whereas measurement of the skin-posterior longitudinal ligament distance overestimates the needle insertion depth by 2.5mm.(35) A well-accepted contributor to underestimation of the depth measurements with ultrasound is compression of the skin and soft tissues by the transducer, and therefore, pressure on the skin must be released prior to freezing an image and measuring the depth to the subarachnoid space.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

12) Use of real-time ultrasound guidance from a paramedian approach may be performed by trained operators; however, this technically challenging approach may not confer any additional advantage over static guidance.
(Round 1 Voting: Weak recommendation with some consensus = "SUGGEST use...")
(Please use the Appropriateness Scale above to select your recommendation)

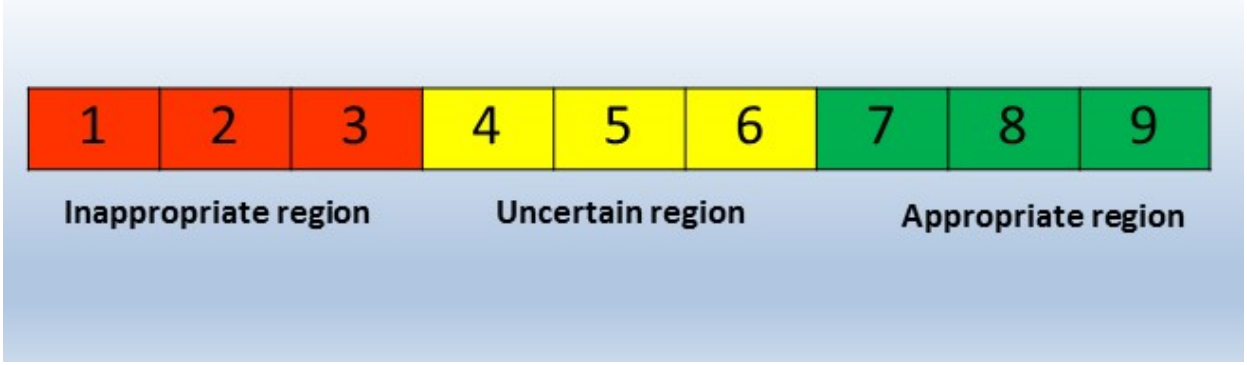
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Few studies have described use of real-time ultrasound guidance for lumbar puncture, epidural catheterization, or spinal anesthesia. A pilot study by Grau et al compared use of landmarks alone, ultrasound-guided site marking, and real-time ultrasound-guided needle insertion. This study found fewer needle insertion attempts and needle redirections with the use of ultrasound guidance, either for site marking or real-time guidance, compared to use of landmarks.(9) Two other pilot studies include one by Karmakar et al that demonstrated successful 1st-attempt epidural catheterization in 14 of 15 (93%) patients (51), and one by Tran et al that showed successful epidural catheterization in 18 of 19 (95%) patients.(52) The largest feasibility study performed by Conroy et al showed successful spinal anesthesia using real-time ultrasound guidance in 97 of 100 (97%) with a median of 3 needle passes.(53) The first randomized study comparing real-time ultrasound guidance vs. landmarks for spinal anesthesia was performed by El Sharkawy. This study was limited by a small sample size (n=32), and although there were marginally longer procedure times, perceived greater difficulty, and marginally higher patient satisfaction scores with real-time ultrasound guidance, no differences were statistically significant.(54)

Currently, no comparative studies using ultrasound for real-time guidance vs. site marking have been published. Performing lumbar procedures with real-time ultrasound guidance requires mastery of needle tracking using a longitudinal (long-axis or in-plane) approach from a paramedian window - a new technique that most providers will require training to perform. Therefore, it is uncertain whether using real-time ultrasound guidance will demonstrate any added benefit to using static ultrasound for site marking.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

13) Use of novel needle tracking devices may facilitate real-time ultrasound guidance but have limited evidence.
(Round 1 Voting: Weak recommendation with good consensus = "SUGGEST use...")
(Please use the Appropriateness Scale above to select your recommendation)

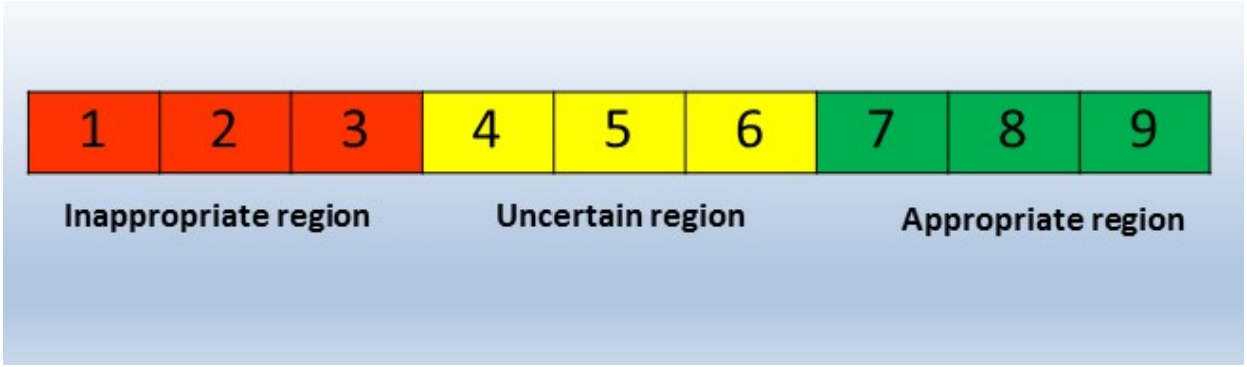
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
A few industry-sponsored studies describe novel needle tracking systems that can facilitate needle visualization during real-time ultrasound guided lumbar puncture. Limitations of these studies include enrolment of a small number of patients and lack of evidence demonstrating superiority of real-time needle visualization vs. site marking with ultrasound. Therefore, use of these novel needle tracking devices have limited supporting evidence.(55,56)

Please add any comments:

Training

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

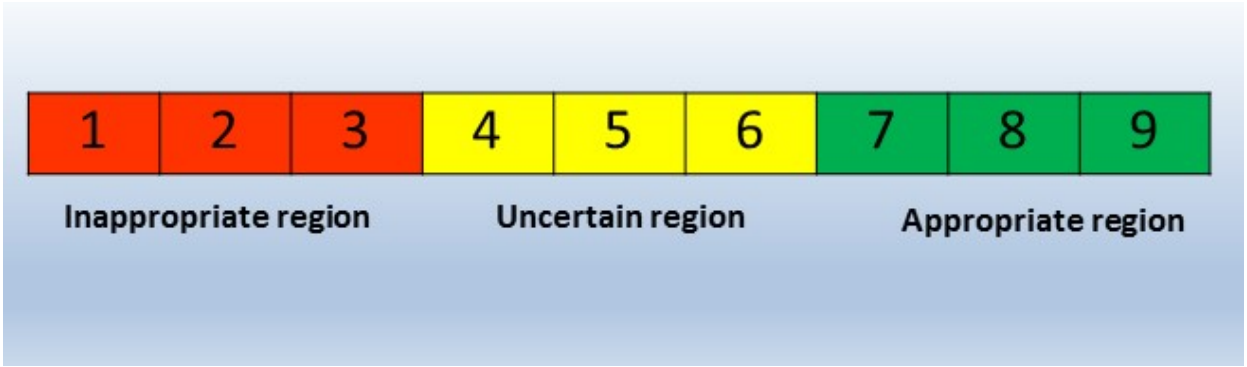
14) Use simulation-based practice to train novice healthcare providers prior to attempting ultrasound-guided lumbar puncture on actual patients. (Round 1 Voting: Weak recommendation with good consensus = "SUGGEST use...") (Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Simulation-based training has been shown to facilitate acquisition of knowledge and skills to perform invasive bedside procedures, including lumbar puncture.(57) Simulation-based training has been commonly incorporated into procedure training for trainees using an immersive experience, as a "boot camp," (58-61) or standardized curriculum (62,63) and has demonstrated improvements in post-course procedural knowledge, technical skills, and/or operator confidence. However, only a few studies included training in the use of ultrasound guidance for lumbar puncture and showed that simulation-based practice improved skill acquisition and/or confidence.(64,65). Simulation using novel computer software may improve skill acquisition in the use of ultrasound guidance for lumbar puncture.(66).

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

15) Adapt training in ultrasound guidance for lumbar puncture based on prior ultrasound experience, as learning curves will vary. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

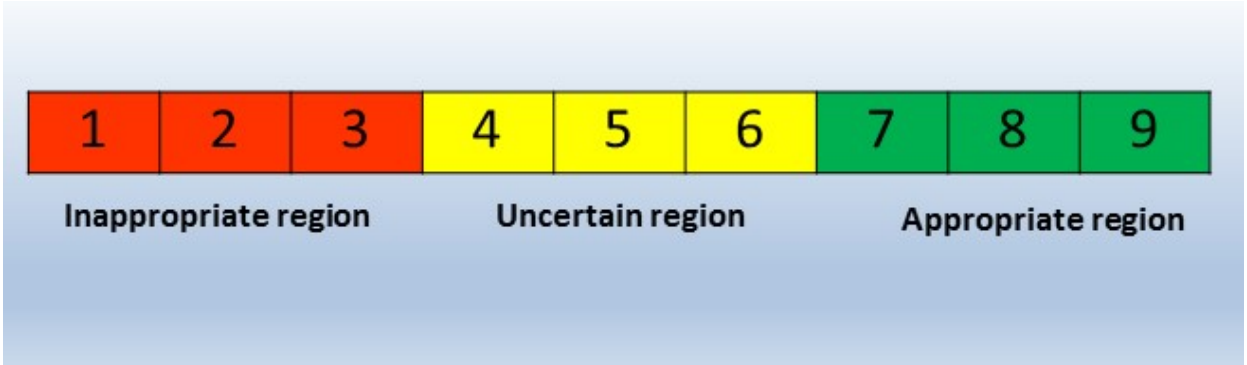
◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
The learning curve to achieve competency in the use of ultrasound guidance for lumbar puncture has not been well studied. A fundamental question that needs to be answered is how to define competency in the use of ultrasound guidance for lumbar puncture, including the specific skills and knowledge that must be mastered. At a minimum, providers must be able to identify lumbar spinous processes and distinguish them from the sacrum; identify the lumbar interspinous spaces; and estimate the depth from the skin to the ligamentum flavum from the midline and paramedian planes.

The rate of attaining competency in identifying lumbar spine structures with ultrasound will vary by provider based on prior skills in ultrasound-guided procedures.(67) One study revealed that 20 supervised ultrasound-guided lumbar punctures was not sufficient to achieve competency in a cohort of practicing anesthesiologists.(68) Novice operators may benefit from practicing lumbar spine mapping of non-obese patients using a high-frequency transducer that generates high resolution images and facilitate recognition of lumbar spine structures.

Please add any comments:

Please use this scale to rank the appropriateness of the recommendation(s) below:



Recommendation:

16) Supervise use of ultrasound guidance by novice providers when performing ultrasound-guided lumbar puncture before permitting independent practice on patients. (Round 1 Voting: Strong recommendation with very good consensus = "SHOULD use...")
(Please use the Appropriateness Scale above to select your recommendation)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ ABSTAIN. I know nothing about this topic.

o Comment:
Demonstration of competency in the use of ultrasound to identify lumbar spine anatomy should be performed before attempting the procedure independently on patients. All providers will require a variable period of supervised practice to demonstrate proper technique, followed by a period of unsupervised practice before competency is achieved. Supervised practice with guidance and feedback has been shown to significantly improve providers' ability to delineate lumbar spine anatomy.(69)

Please add any comments:

Please provide any final thoughts or comments about this position statement.

Appendix 5 – Final Voting Results for Lumbar Puncture Recommendations

Approved Recommendations with strong endorsement
Approved Recommendations with weak endorsement
Unapproved Recommendations, with disagreement

Recommendation	# of Panelists	Median	Zone	# of votes out of Zone	# of votes within X of median			Consensus
					1 pt	2 pts	3 pts	
1: Use ultrasound guidance for site selection of lumbar puncture to reduce the number of needle insertion attempts and needle redirections, and increase overall procedure success rates, with the greatest benefit demonstrated in obese patients.	27	8	Appropriate	4 (15%)	23 (85%)	→	→	Very Good
2: Use ultrasound guidance for lumbar puncture to reduce post-procedure back pain and improve patient satisfaction with the greatest benefit shown in overweight or obese patients.	27	7	Appropriate	13 (48%)	→	→	→	No
3: Use ultrasound guidance for lumbar puncture to reduce the risk of a traumatic tap.	25	7	Appropriate	11 (44%)	→	→	→	No
4: Use ultrasound guidance to select a needle insertion site for lumbar puncture which may reduce patient exposure to ionizing radiation from fluoroscopy.	27	8	Appropriate	2 (7%)	25 (93%)	→	→	Very Good
5: Ultrasound mapping of the lumbar spine can be performed in either a lateral decubitus or sitting position.	26	7.5	Appropriate	7 (27%)	12 (46%)	22 (85%)	→	Good
6: Using a sitting position widens the interspinous spaces and may be preferred if measurement of opening pressure is not needed.	26	7	Appropriate	9 (35%)	→	→	→	No

7: Use ultrasound to more accurately identify the lumbar spine level than physical examination in both obese and non-obese patients.	27	8	Appropriate	1 (4%)	26 (96%)			Very Good
8: Use a low frequency curvilinear transducer to evaluate the lumbar spine and mark a needle insertion site. A high frequency linear transducer may be used in non-obese patients.	27	8	Appropriate	1 (4%)	26 (96%)			Very Good
9: To map the lumbar spine, start at the level of the sacrum and slide the transducer cephalad, sequentially identifying the lumbar spine interspaces.	27	8	Appropriate	0 (0%)	27 (100%)			Very Good
10: Use ultrasound in a transverse plane to mark the midline of the lumbar spine and a longitudinal plane to mark the interspinous spaces. The intersection of these two lines marks the needle insertion site.	27	9	Appropriate	0 (0%)	25 (93%)			Very Good
11: During a pre-procedural ultrasound evaluation, measure the distance from the skin surface to the ligamentum flavum from a longitudinal paramedian view to estimate the needle insertion depth and ensure an adequate length spinal needle is used.	27	8	Appropriate	0 (0%)	27 (100%)			Very Good
12: Use of real-time ultrasound guidance from a paramedian approach may be performed by trained operators; however, this technically challenging approach may not confer any additional advantage over static guidance.	24	6	Uncertain	11 (46%)				No
13: Use of novel needle tracking devices may facilitate real-time ultrasound guidance but have limited evidence.	26	6	Uncertain	12 (46%)				No

14: Use simulation-based practice to train novice healthcare providers prior to attempting ultrasound-guided lumbar puncture on actual patients.	27	8	Appropriate	4 (15%)	23 (85%)	→	→	Very Good
15: Adapt training in ultrasound guidance for lumbar puncture based on prior ultrasound experience, as learning curves will vary.	27	9	Appropriate	0 (0%)	22 (81%)	→	→	Very Good
16: Supervise use of ultrasound guidance by novice providers when performing ultrasound-guided lumbar puncture before permitting independent practice on patients.	27	9	Appropriate	0 (0%)	24 (89%)	→	→	Very Good