Detecting host responses to microbial stimulation using primary epithelial organoids

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Assessment of Technical Competence in Distal Radius Fracture Fixation by a Volar Locking Plate: A Global Delphi Consensus Study

Mads Emil Jacobsen, MD,*†‡ Leizl Joy Nayahangan, RN,† Monica Ghidinelli, PhD,§ Chitra Subramaniam, PhD,|| Kristoffer Borbjerg Hare, MD, PhD,*,† Lars Konge, MD, PhD,†‡ Amandus Gustafsson, MD*†‡

Purpose Volar locking plate fixation of distal radius fractures is a common orthopedic procedure and should be mastered by graduating orthopedic residents. Surgical education is transitioning from a traditional time-based approach to competency-based medical education. Valid and objective assessment is essential for successful transition. The purpose of this study was to develop a comprehensive, procedure-specific assessment tool to evaluate technical competence in volar locking plate osteosynthesis of a distal radius fracture.

Methods International orthopedic/trauma experts involved in resident education participated as panelists in a four-round online Delphi process to reach consensus on the content of the assessment tool. Round 1 was an item-generating round, in which the panelists identified potential assessment parameters. In round 2, the panelists rated the importance of each suggested assessment parameter and reached consensus on which to include in the assessment tool. Round 3 yielded specific assessment score intervals for specific bone and fracture models and is not reported in this study. In round 4, the panelists assigned weights to the assessment parameters on a 1—10 scale to determine how each parameter should have an impact on the overall results.

Results Eighty-seven surgeons, representing 42 countries, participated in the study. Round 1 resulted in 45 assessment parameters, grouped into five procedural steps. After round 2, the number of parameters was reduced to 39. After the final round, an additional parameter was removed and weights were assigned to the remaining parameters.

Conclusions Using a systematic methodology, a preliminary assessment tool to evaluate technical competence in distal radius fracture fixation was developed. A consensus of international experts supports the content validity of the assessment tool.

Clinical relevance This assessment tool represents the first step in the evidence-based assessment essential for competency-based medical education. Before implementation, further studies exploring validity of variations of the assessment tool in different educational contexts are required. (J Hand Surg Am. 2023;48(9):875—885. Copyright © 2023 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).)

Key words Assessment of surgical skills, competency-based medical education, Delphi, distal radius fracture, volar locking plate.
DISTAL RADIUS FRACTURES (DRFs) are among the most common orthopedic injuries, and their incidence is increasing. As a result, DRFs are the cause of substantial patient morbidity and cost, both for the individual patient and society. Consequently, the management of DRFs, including surgical treatment, is consistently reported in the literature as an important skill to master by graduating orthopedic residents. Application of a volar locking plate is a frequent method for surgical fixation of DRFs. Surgical education traditionally relies on a time-based model. In this model, experience is considered to be the primary contributor to development of skill and constitutes the main measure of competence. However, considerable differences in competence exist even among surgeons with high case volumes and similar duration of practice, affecting patients’ outcomes. Additionally, work-hour restrictions, concerns for medical litigation, and operating room efficiency have further questioned the adequacy of time-based education. As a response, residency programs around the world are moving toward competency-based medical education (CBME), which is an approach for preparing physicians for practice that focuses on the acquisition of specific skills, knowledge, and behaviors based on the analysis of societal and patient needs. It is a learner-centered approach that prioritizes the achievement of competencies as opposed to completing a predetermined length of training. Along with this shift in educational strategy, simulation has become increasingly popular as an approach to teach and assess surgical skills. Simulation offers the possibility of deliberate practice in a risk-free environment, and mounting evidence shows that simulation-based training translates into better patient outcomes.

Valid and objective assessment is an essential part of CBME. In CBME, assessment serves not only as a measure of what has been learned but also, more importantly, as a means of driving learning through formative and summative feedback. This feedback is critical for promoting and achieving competence. The Objective Structured Assessment of Technical Skills (OSATS) tool is commonly used in hand surgery, but it has been demonstrated to be unreliable in assessing the quality of DRF fixation results. Consequently, the rationale for this study is the need for an assessment tool to specifically evaluate surgical competence in open reduction internal fixation of DRFs.

Using an international panel of orthopedic/trauma experts, the aim of this study was to develop a preliminary and comprehensive assessment tool to evaluate technical competence in volar locking plate osteosynthesis of a DRF in various educational contexts.

MATERIALS AND METHODS

This study was a global, modified four-round Delphi process. The study followed the Checklist for Reporting Results of Internet E-Surveys because the surveys of the study were exclusively conducted online (see Supplementary Table S1, available online on the Journal’s website at www.jhandsurg.org). The regional ethics committee of Region Zealand, Denmark deemed the study exempt from ethical approval.

The Delphi method is a widely accepted approach to establish consensus among experts in a given field of interest. The method has been used in various disciplines, particularly within curriculum development and educational research. The Delphi method facilitates convergence of expert opinion by employing survey iterations over several rounds. Important features of the method are structured feedback between survey iterations as well as anonymity of panelists, which helps reduce the influence of dominant individuals.

The study took place from February 2021 to September 2021 and consisted of four survey rounds. Survey deadlines ranged from 19 to 49 days, depending on survey length and vacation periods. The intervals between each round varied from 14 to 49 days, allowing for sufficient time to perform between-round analyses. The goal was to achieve expert consensus on the content of individual assessment tools for seven different osteosyntheses, encompassing basic principles of osteosynthesis (see Supplementary Table S2, available online on the Journal’s website at www.jhandsurg.org). The current report focuses only on volar locking plate fixation of a simple, intra-articular fracture of the distal radius. All surveys were administered individually to each panelist through the online survey platform.
SurveyMonkey (see Supplementary Figure 1, available online on the Journal’s website at www.jhandsurg.org, for examples of online surveys). All survey items were mandatory.

Steering committee
A steering committee of seven members, consisting of orthopedic specialists and medical education scientists, supervised, monitored, and managed all processes in the Delphi study.

Panelists
International experts and postgraduate educators in the field of orthopedic traumatology were invited to participate in the study as panelists. Inclusion criteria for panelists were as follows: (1) faculty of AO Foundation (AO) trauma course “Basic Principles of Fracture Management,” (2) faculty of AO trauma course “Advanced Principles of Fracture Management,” and (3) colleagues, suggested by one of the above, who are actively involved in training of orthopedic residents (had to be suggested before or during round 1). Exclusion criteria were as follows: (1) not an active trauma surgeon and (2) not supervising resident surgeons as part of clinical practice. We chose to invite AO faculty members to participate because of their inherent interest in surgical education. Furthermore, the process of becoming an AO faculty involves a rigorous selection of highly competent surgeons, who are then thoroughly trained through a comprehensive faculty development program. Potential panelists were identified through an email list of AO trauma course faculty available only to one author (M.G.). Three hundred fifty-five experts were invited by an email that explained the background and purpose of the study and contained a hyperlink to the study and contained a hyperlink to the study. Written consent was obtained from all participating panelists.

The Delphi rounds
Round 1: Item generation: In this round, the panelists were asked the following three questions: (1) “Please list all technical aspects (assessment parameters) that you find relevant to assess when determining how well a locking plate osteosynthesis of a simple, intra-articular (sagittal split) fracture of the distal radius with a stable distal radioulnar joint (AO/OTA 2R3C1.2.t) is performed by a novice resident”; (2) “Based on your experience, please list the most common errors relating to residents’ technical performance of the osteosynthesis ie, frequent/typical errors made by novice residents relating to osteosynthesis”; and (3) “Based on your experience, please list the most critical errors relating to residents’ technical performance of osteosynthesis ie, severe errors that jeopardize the surgical result/patient outcome.” All responses were reviewed, grouped into procedural steps by means of content analysis, and condensed by the steering committee. Exact duplicates were deleted. Responses to questions 2 and 3 were used to further define and articulate the assessment parameters that were identified in question 1 (eg, “Placing too long distal screws” was rewritten into the assessment parameter “Length of the distal screws”). The resulting pool of assessment parameters was then evaluated by the steering committee on the basis of the prespecified criteria that are found in Table 1.

Round 2: Importance rating and consensus: The reviewed list of assessment parameters was sent back to the panelists for importance rating. Panelists were asked to rate the importance of each assessment parameter to be included in the assessment tool on a five-point Likert-like scale, labeled as follows: 1—not important, 2—somewhat important, 3—important, 4—very

<table>
<thead>
<tr>
<th>TABLE 1. Prespecified Evaluation Criteria for Assessment Parameters in Delphi Round 1</th>
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<tbody>
<tr>
<td><strong>Inclusion Criteria</strong></td>
</tr>
<tr>
<td>1. Assessment parameters evaluating technical performance/skills</td>
</tr>
<tr>
<td>2. Assessment parameters relating strictly to the performance of the osteosynthesis and fluoroscopic control</td>
</tr>
<tr>
<td>3. Assessment parameters that could be incorporated into automated assessment metrics on a virtual reality simulator</td>
</tr>
<tr>
<td><strong>Exclusion Criteria</strong></td>
</tr>
<tr>
<td>1. Assessment parameters relating to nontechnical skills (eg, preoperative planning, communication, teamwork, etc.)</td>
</tr>
<tr>
<td>2. Assessment parameters relating to technical performance other than the osteosynthesis and fluoroscopic control (eg, exposure, soft tissue handling, closure, fluoroscopy of contralateral side for templating, etc.)</td>
</tr>
<tr>
<td>3. Assessment parameters relating to prespecified standardized settings of the procedures (eg, patient position, osteosynthesis method, etc.)</td>
</tr>
<tr>
<td>4. Assessment parameters relating to time spent, as this parameter will be inherent in all assessments in the simulated setting</td>
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</table>
important, and 5—extremely important. Consensus for inclusion of a parameter in the assessment tool was defined *a priori* as a mean rating of “3—important” or above. Assessment parameters that did not reach this threshold were eliminated.

**Round 3: Definition of optimal intervals and borderline error values:** This round was performed to enable automated assessment and feedback on a virtual reality simulator that is under development. Data from this round relate to specific bone and fracture models relating to the development of the virtual reality simulator and are not reported here.

**Round 4: Weight assignment:** In this final round, panelists were asked to assign a weight to each of the assessment parameters for which consensus was found after round 2. This was to acknowledge that although all remaining assessment parameters were considered “important” in round 2, they should not necessarily affect the final assessment score equally. Panelists were asked to assign weights from 1 (low impact) to 10 (high impact). Final weight of each parameter was calculated as mean of the weights allocated by each panelist.

**Data analysis**

Manual content analysis by the steering committee was used to review the data after round 1, and descriptive statistics were performed from round 2 through 4. Correlations were calculated as Pearson’s *r* with 95% confidence intervals. Statistical significance level was set at *P* < .05. Questionnaires with at least one answer were counted as partial. All questionnaires, including partial answers, were analyzed. Complete and partial responses were totaled and included in the calculation for response rates in each round.

**RESULTS**

A flowchart of the Delphi process for the DRF is shown in Figure 1. From the 355 experts invited to participate, 119 individuals clicked on the survey link. Of these, 11 provided no data and four did not meet the inclusion criteria. Six declined to participate. In total, 98 individuals agreed to participate and provided personal information, resulting in a recruitment rate of 28%. Of the 98 individuals who agreed to participate, 11 (11%) did not provide any inputs in any of the four rounds and, thus, were not counted as panelists but were still included in the calculation of response rates. Characteristics and geographical distribution of the 87 participating panelists are found in Table 2 and Figure 2.

The response rate for round 1 was 82 of 98 (84%). Saturation was obtained, ie, no new assessment parameters were identified when reviewing the last one-third of the questionnaires. A total of 179 assessment parameters were identified after initial screening, which included removal of exact duplicates and condensation of identical parameters. After thorough review by the steering committee, 74 assessment parameters were excluded on the basis of the prespecified criteria (Table 1). Further condensation, owing to redundancies, removed another 60 assessment parameters. Examples of excluded parameters are found in Table 3. Thus, round 1 yielded a total of 45 assessment parameters.

The response rate for round 2 was 65 of 98 (66%). The assessment parameters received a mean importance rating of 3.72 (SD, 0.53), and the range for mean importance ratings of the assessment parameters was 2.39–4.66. Six assessment parameters were excluded after round 2. Of these, four did not meet the consensus criterion and two were excluded after further review by the steering committee for being related to a standardized setting and redundancy, respectively (Table 3).

The response rate for round 4 was 46 of 98 (47%). One assessment parameter was excluded owing to redundancy after final review by the steering committee (Table 3). The remaining 38 assessment parameters received a mean weight of 8.11 (SD, 0.74). The range of average weights for the assessment parameters was 6.8–9.4. There was a statistically significant and strong correlation between the average importance in round 2 and average weight in round 4 for the final 38 assessment parameters: Pearson’s *r* = 0.94 (95% confidence interval, 0.88–0.97), *P* < .001. The final list of assessment parameters is presented in Figure 3. Individual importance ratings and weights for all assessment parameters are listed in Supplementary Table S3, available online on the Journal’s website at www.jhandsurg.org.

**DISCUSSION**

The aim of this study was to develop an assessment tool to evaluate technical competence in volar locking plate osteosynthesis of a DRF. A four-round Delphi process resulted in a comprehensive list of 38 parameters that international experts considered important to assess. Eleven parameters pertain to reduction and temporary fixation, mostly reflecting reduction methods that the panel regarded appropriate for the specific fracture.
Plate placement yielded five assessment parameters. Items 15 and 17 are in line with current evidence, demonstrating increased risk of complications with increased volar prominence and distal placement of volar locking plates.\textsuperscript{26,27} The impact of plate rotation is less studied. Nevertheless, a recent study suggests that increasing rotational malposition of the plate, in relation to the long axis of radius, results in an increased level of edema fluid around the flexor pollicis longus tendon, indicating irritation.\textsuperscript{28}

Ten parameters related to screw placement. Intra-articular screw placement is a major complication, often requiring secondary surgery for implant removal.\textsuperscript{29,30} Regarding item 26, the length of the distal screws is a well-studied matter: screws protruding beyond the dorsal cortex contribute to tendon complications.\textsuperscript{31–33} Further, unicortical compared with bicortical distal screws have been demonstrated to not substantially lower construct strength.\textsuperscript{34,35}

The panelists agreed that assessing the surgical result requires multiple fluoroscopic projections. The list includes five projections: anterior—posterior, posterior—anterior, standard lateral, lateral facet view (ie, elevated wrist), and a tangential view. This aligns with the existing literature, which implies that no single view is sufficient to evaluate the surgical result, including screw penetration of the joints and the dorsal cortex.\textsuperscript{36}
Our findings have limitations owing to the composition of our panel, consisting of orthopedic trauma surgeons (albeit with some reporting practice in hand surgery as well). This choice was made to ensure a qualified panel for addressing questions on all seven different fractures in various anatomic locations. Although this approach excluded the specialized expertise of hand surgeons practicing exclusively in hand surgery (including plastic and/or general surgery primarily trained), we do not believe that this reduces the generalizability of our results. Orthopedic traumatologists often treat and educate on these common cases. Another possible limitation is the potential underrepresentation of a particular sex, as we did not collect information on the sex of our panelists.

Although we believe that the number of completed questionnaires does not fall short of suggested numbers in any of the rounds, our results should be interpreted in light of our recruitment rate of 28% and modest response rates. This may be because of our recruitment method, as we sent email invitations without prior inquiry. Also, we are unsure whether all invited participants received the invitation or were qualified to participate. A large number of panelists, intentionally chosen for comprehensiveness and global input, may have also affected response rates, as keeping a large panel engaged is more difficult than keeping a smaller panel engaged. Time consumption is a known barrier of the Delphi method, especially with larger panels.24

The large number of assessment parameters is a result of the liberal criterion for consensus compared with similar studies.38,39 A known limitation of defining more strict consensus criteria in Delphi processes is that it may fail to capture important items.22 Although we acknowledge that the number of parameters may not be feasible in the clinical setting, we pursued an assessment tool comprehensive enough that it can be adapted and validated for educational purposes in different educational contexts.

The purpose of round 4 was to recognize that all parameters should not necessarily affect the final assessment score equally. Although the individual parameters were assigned different weights, the differences were small. Consequently, the weights did not reflect the intended differentiation of assessment scores. The strong correlation between importance scores in round 2 and weights in round 4 confirmed the importance of the parameters. However, the original purpose of weighting could have been better realized had the panel been asked to rank-order the parameters or if weights had been assigned by a different panel than the one reaching consensus on importance.

The assessment parameters only pertain to the bone management aspect of fixing a DRF using a volar locking plate and do not cover other important steps, such as approach, soft tissue handling, closure, etc. These steps were omitted because we believe that they can be adequately assessed by the existing generic OSATS.19,40 When OSATS is used to assess established predictors of quality in fracture surgery, however, it seems less robust. Hopmans et al used OSATS to assess performance and observed reliable discrimination among residents at different postgraduate training years for four different

### TABLE 2. Characteristics of the Panelists

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Panelists, n = 87</th>
<th>Panelists Participating in all Delphi Rounds, n = 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of years as orthopedic/trauma specialist,</td>
<td>17 (4–35)</td>
<td>17.5 (4–35)</td>
</tr>
<tr>
<td>median (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience supervising surgical education of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>orthopedic/trauma residents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–5 y, n</td>
<td>1 (1.1%)</td>
<td>1 (2.5%)</td>
</tr>
<tr>
<td>6–10 y, n</td>
<td>24 (27.6%)</td>
<td>10 (25%)</td>
</tr>
<tr>
<td>11–15 y, n</td>
<td>17 (19.5%)</td>
<td>8 (20%)</td>
</tr>
<tr>
<td>More than 15 y, n</td>
<td>45 (51.7%)</td>
<td>21 (52.2%)</td>
</tr>
<tr>
<td>Practicing in hand surgery besides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>traumatology, n</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>AO faculty, yes:no</td>
<td>86:1</td>
<td>40:0</td>
</tr>
</tbody>
</table>

AO, AO Foundation.
surgeries except the osteosynthesis of a proximal femoral fracture, which they attributed to the simplicity of the operation. In contrast, we believe that valid assessment of the required skillset for fracture surgery is complex. This is further qualified by studies demonstrating OSATS’s lack of ability to capture key quality parameters, such as tip-apex distance and accuracy of intra-articular fracture reduction. Importantly, for DRF fixation specifically, the OSATS has shown only moderate utility, calling for new assessment tools to be developed and validated.

Simulation-based education in technical skills is pivotal in the successful transition to CBME in hand surgery. Simulation enables deliberate practice along with immediate assessment and feedback, with no risks to patients. Basic principles of osteosynthesis were the first priority in a general needs assessment, identifying which technical procedures to integrate in a simulation-based curriculum.

This work represents the next step in systematic curriculum development, as our assessment tool defines specific learning goals and objectives for the procedure. The consensus of international experts provides robust validity evidence for the content of the assessment tool. The assessment tool can serve as the starting point for the development of a virtual reality simulator for performing open

**FIGURE 2:** Geographical distribution of the panelists. Map created with mapchart.net.
reduction and internal fixation of DRFs by providing a scaffold for automated assessment and feedback. In the clinical setting, the list of parameters can readily be used for formative feedback. Pending condensation and validation, it has potential to serve as a valuable instrument for summative feedback and clinical assessment.

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Figure 3: Final list of assessment parameters for locking plate osteosynthesis of a simple, intra-articular, and distal radius fracture with a stable DRUJ. AO/OTA, AO Foundation/Orthopedic Trauma Association fracture classification; Avg, average; DRUJ, distal radioulnar joint; ROM, range of motion; SL, scapholunate.
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