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Innovation Meets Practice: A Scalable Simulation-based Methodology for Massive Paracentesis Training

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Simulation-based training provides realistic learning environments, allowing skill development without patient risks.[1] Despite successful applications in gastroenterological procedures,[2–4] implementing simulation-based training optimally remains challenging.[1] Although research often emphasizes high-fidelity simulators and emerging technologies, a gap persists: the need for trainers. Trainers provide feedback, facilitating progression through a learning curve and toward competence.[1,5,6] However, the availability of qualified instructors is often insufficient for training large cohorts, compromising training scalability.[1,7]

Feedback is vital for skill development, enhancing both learning and retention.[5,6] Critical elements of feedback include *who* delivers it and *how*. Regarding *who*, when experts are not available, trained nonexperts, peer, and near-peer tutors have emerged as alternatives to augment teaching teams.[8–10] Yet, sustainable training with multiple feedback-driven sessions remains challenging owing to resource limitations and scarce teacher availability.[1,6,7] Consider a cohort of 120 medical students per year who need to acquire multiple procedural skills within a limited timeframe. How to effectively train this volume of students? How can competency be measured? How can feedback be efficiently delivered?

Technology addresses *how* feedback is given, with asynchronous modalities allowing a more flexible participation in the learning process, fostering autonomy.[7,11–15] We shifted from single-session training schemes to a scalable training environment using a feedback-oriented web-based platform. To date, we have successfully implemented this modality in various medical disciplines such as surgery,[14] critical care,[13] and physiotherapy,[15] among others. The purpose of this study was to comprehensively explain this methodology and its results, applied on medical students who participated in a paracentesis course. This skill has been prioritized owing to the limited availability of gastroenterologist in some regions of our country, making it a fundamental competence for general practitioners.

Methods

Institutional Context, Course Validation, and Transfer to the Real Scenario

Third-year medical students participated in a simulation-based paracentesis course designed to teach and train how to perform diagnostic and large-volume paracentesis. Local data supported that trained students after a fourth-session course could safely perform a paracentesis on a real patient (Figure 1). Moreover, from their second simulated attempt onwards, performance was comparable to what was registered on the real clinical scenario (Figure 1, Supplementary Figure 1). Then, through a randomized controlled trial, we demonstrated that the remote-asynchronous modality not only matched, but exceeded the success rate of that face-to-face course, which had previously been proven effective in skill transfer to clinical scenarios.[16] Taken together, these findings provided a strong rationale for transitioning the curriculum to the remote modality, although further evaluation in nonexperimental settings was still required.

Educational Platform

We developed a web and mobile feedback-oriented platform where an administrator can create courses divided into stages. Students' progress through stages by reviewing videos, completing quizzes, uploading videos, and receiving feedback

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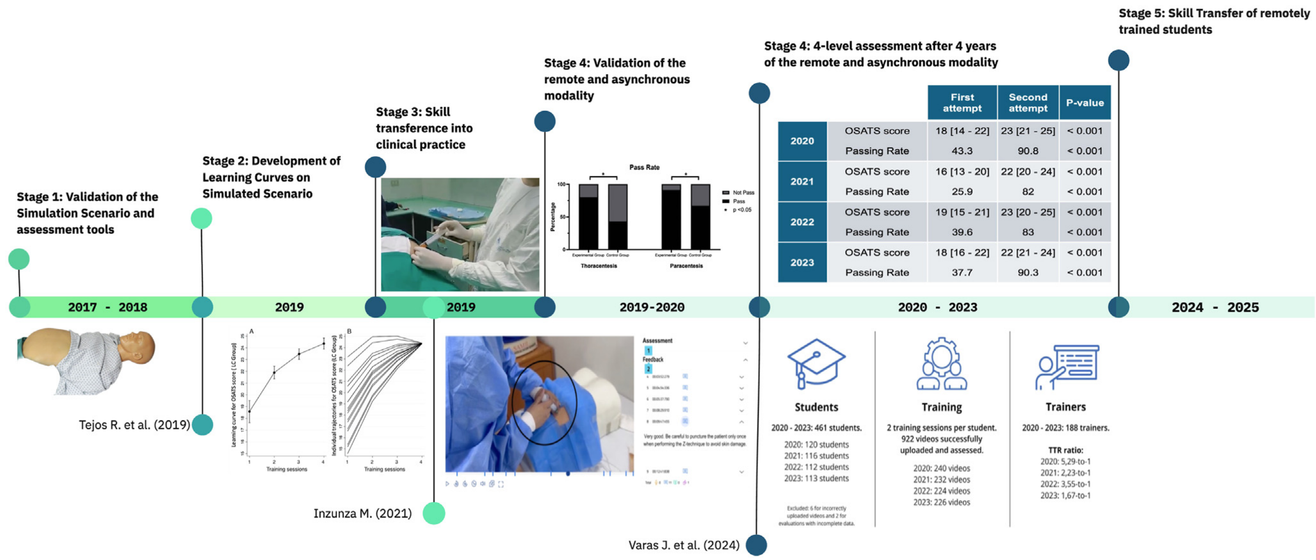

Figure 1. Timeline of the paracentesis course validation stages and results.

asynchronously. Data were prospectively stored and monitored via the platform.

Instructors and Train the Trainers

Given the cohorts' size, a standardized teaching group was established. Initially, clinical experts were involved, but owing to calibration issues and dropouts, we recruited medical students and residents as teachers. These nonclinical experts underwent a train the trainers (TTT) course in which they learned concepts about feedback and paracentesis. Afterward, they were tasked with giving effective feedback on standardized videos. Details and results of this TTT have been published elsewhere.[8]

Logistics

Course coordination, including dates, schedules, and participant management, was handled by the skills lab team. Students were added to the platform in advance to begin reviewing theoretical material, and communication channels were established.

Simulated Training

After completing theoretical stages in which the basis of paracentesis was learned, students engaged in simulated practice at the skills lab. Each student performed 2 training sessions using puncturable paracentesis models.[2] Students were paired and given 30 minutes to perform and record the procedure (once each) using their cellphones. Videos were uploaded to the platform, where trainers provided asynchronous feedback within 72 hours. The team ensured all students completed their 2 attempts within a 6-week timespan (Figure 1).

Assessment Tools and Outcomes

Performance was evaluated using a modified Objective Structured Assessment of Technical Skills (OSATS)[17] and a Procedure-Specific Rating Scale (PRS).[2] The minimum passing score for OSATS was set at 20 out of 25 (80%). Procedural time was excluded from analysis owing to confounding factors like peer assistance. Time intervals between video uploads and feedback reception were registered.

Course Evaluation and Students' Perceptions

Upon course completion, students were surveyed to collect their perception, rating the course on a scale of 1 to 7 (with 7 being the best). Organization, feedback quality, infrastructure and materials, and overall appreciation were assessed.

Subjects and Inclusion Criteria

Third-year medical students who participated in the paracentesis course from 2020 to 2023 were included. Only data from students with complete pre- and post-feedback video assessments were analyzed. Incomplete, repeated, or edited evaluations were excluded.

Statistics

Nonparametric statistics were used. Descriptive statistics, including medians [p25–p75] and percentages, are presented. Medians were compared using Wilcoxon's signed-rank test; correlations were determined using Spearman's test. RStudio was used for analysis.

Ethics

The institutional review board approved the validation of this methodology before implementing the course as mandatory (ID: 190329010). Data were anonymized and collected retrospectively.

Results

During the study period (2020–2023), 461 of 469 students who participated in the paracentesis course were included. Eight students were excluded: 6 incorrectly uploaded videos (edited, duplicated, or corrupted videos), and 2 had incomplete evaluations. A total of 922 videos successfully uploaded and assessed were included for analysis.

Regarding the TTT course, 188 participants completed the training and were subsequently designated as trainers. The trainees to trainer ratio (TTR) ranged from 5.29-to-1 in 2020, to 1.67-to-1 in 2023 (Figure 1).

Students' Performance

A passing rate of 85.46% was achieved, with 394 students obtaining the minimum OSATS score. The median OSATS score improved from 18 [14–21] on the first attempt, to 23 [20–25] after feedback ($P < .001$). Similarly, median PRS score improved from 20 [16–23] to 25 [23–26] ($P < .001$). Overall, 365 (79.18%) and 369 (80.04%) students improved their OSATS and PRS, respectively, on their second attempt (Figure 1).

A total of 4220 feedback inputs were provided (considering only first attempts), with a median of 9 [6–13] per video. Of these, 77.08% (n = 3253) were text comments, 14.74% (n = 622) were voice recordings, and 8.18% (n = 345) were on-screen drawings. The median interval between video upload and feedback reception, was 4 days [2–10 days]. Thereafter, time span from feedback reception until the second video upload was 18 days [9–22 days].

Correlation and Analysis

Univariate analysis showed a significant association between improvements in OSATS and PRS scores ($\rho = .6154$; $P < .001$). A moderate positive correlation was observed between pre- and post-feedback OSATS scores ($\rho = .3188$; $P < .001$) and a weak positive correlation for PRS scores ($\rho = .2079$; $P < .001$). The number of feedback inputs correlated weakly with score improvements for both OSATS ($\rho = .1924$; $P < .001$) and PRS ($\rho = .2325$; $P < .001$). Feedback delay from first attempt did not influence performance ($\rho = -.032$; $P = .5449$) nor time from feedback reception until the second attempt ($\rho = -.09$; $P = .079$). The TTR had no measurable impact on improvement.

Students' Perception

The course received ratings of 6.5, 5.9, 6.5, and 6.4 for years 2020, 2021, 2022, and 2023, respectively. Median ratings for organization, quality of feedback, and infrastructure and materials were 6.7, 6.1, and 6.7, respectively.

Discussion

Medical and procedural teaching is increasingly complex, particularly in environments with limited resources and faculty, posing significant challenges for academic institutions. Simulation-based training offers realistic, risk-free skill development, yet its optimal implementation and scalability depends on the need for qualified trainers.

Our study describes the implementation of an undergraduate course designed for scalable learning within a structured paracentesis program. This method has been effective in contexts with limited time, resources, and trained instructors. Applying the Kirkpatrick framework,[18] we gathered data across all levels (Figure 2). At "Level 1:

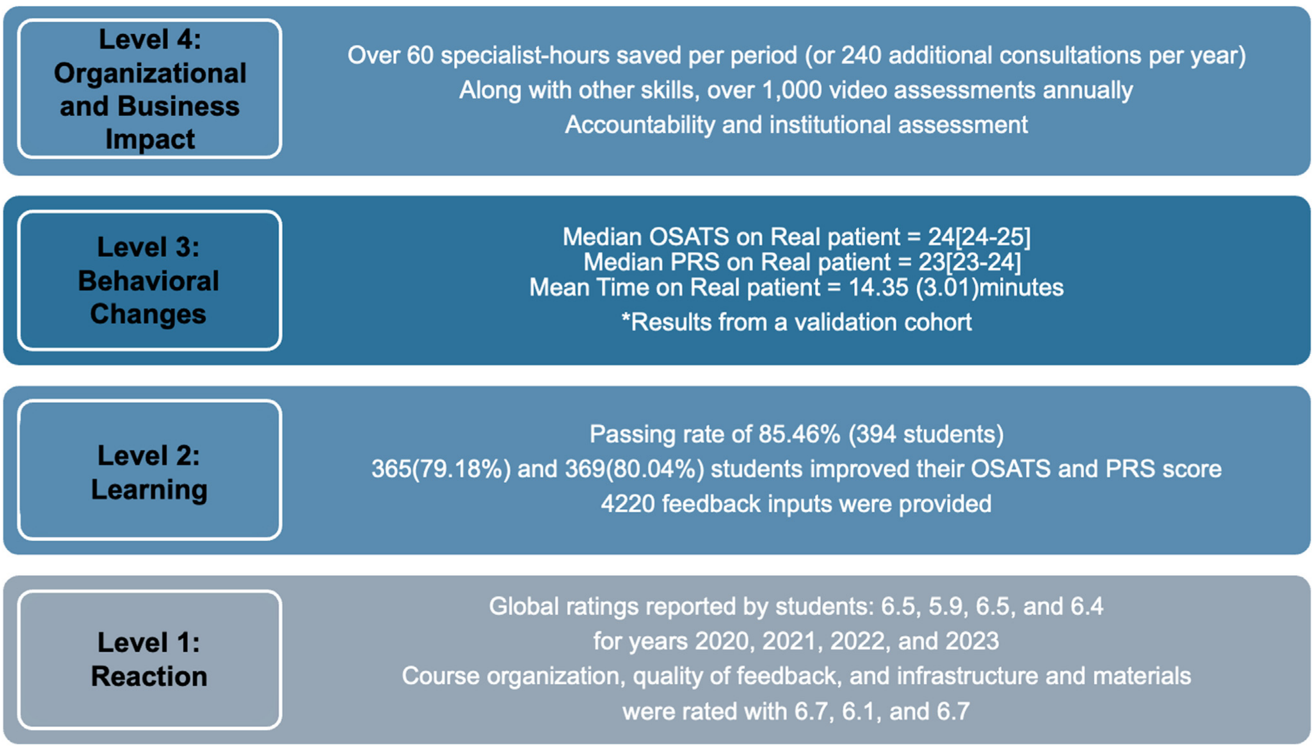

Figure 2. Quantitative results based on Kirkpatrick framework. Adapted from: Kirkpatrick D, Kirkpatrick J. Evaluating training programs: the four levels. Oakland, CA: Berrett-Koehler Publishers, 2006.

Reaction," students highly valued the paracentesis training sessions, corroborating previous research.[2] At "Level 2: Learning," we successfully trained nearly 120 students annually, achieving an 85% passing rate. This result demonstrates the feasibility, effectiveness, and scalability of simulation training using remote and deferred feedback. A limitation of this study is that the transfer of the skills acquired by these cohorts into clinical practice has yet to be measured. However, previous validation studies suggest, first, that performance on the simulated scenario would not differ from performance on a patient in a controlled setting (Figure 1), and second, that the asynchronous modality is at least equivalent to the face-to-face modality.

At "Level 3: Behavioral Changes," although not measured directly, student feedback suggested that skills acquired, would likely motivate them to perform the procedure more confidently on patients (Supplementary Figure 2). At "Level 4: Organizational and Business Impact," institutional benefits were substantial. By reducing the need for gastroenterologists and residents as trainers, we saved more than 60 specialist-hours per period, potentially allowing for 240 additional patient consultations per year (based on 4 consultations per hour and 10 specialists canceling nearly 6 hours of clinical duties annually owing to the course). At a university level, the paracentesis course and others on our platform, generate more than 2000 video assessments annually, ensuring accountability for student competency and enhancing educational research.

Regarding educational data, our study supports previous research on the TTT model, which enables a scalable increase in the number of teachers.[8,9,19] One-hundred eighty-eight paracentesis trainers participated, providing effective feedback to students that showed significant improvement, adding evidence to peer or near-peer evaluation. Interestingly, the TTR had no impact on measured scales, suggesting that trainers did not reach a saturation point that would compromise teaching; however, it is worth mentioning that trainers also assisted other courses simultaneously. Pertaining to feedback analysis, a weak correlation between the quantity of inputs and skill improvement was found. How quality of feedback correlates with skill improvement was not addressed. Nevertheless, in another undergoing study, preliminary results (obtained from the 2023 cohort) show a positive correlation between feedback quality and OSATS improvement, and using a multivariate model, feedback quality accounted for the 13.16% of the variance in OSATS change (data not published). Concerns about feedback delay negatively affecting performance were unsupported by our data.

Creating conditions for iterative training is a critical and challenging element of deliberate practice.[6] Our paracentesis course offered 2 training sessions per student, which may not allow proficiency; however, this 2-session course provided valuable insights. First, skill improvement was demonstrated using 2 validated scales, supporting that the use of remote and deferred feedback effectively enhances skill acquisition. Second, although many undergraduate courses are sporadic, our experience suggests that the autonomous repetition under the same controlled setting, positively impacts performance by reducing anxiety and empowering students (Supplementary Figure 2). In 2021, a lower rating led us to hold an open focus group with students to assess the course. After their concerns were addressed, an improvement in their perception was obtained, emphasizing the value of open dialogue with students.

From a clinical perspective, learning paracentesis is essential for undergraduate students in regions where timely access to a gastroenterologist is challenging. Achieving competency in paracentesis before graduation is driven by local educational mandates and the global demand for gastroenterology-related procedures.[20] A limitation of this study is that we have not assessed these cohorts on real patients or evaluated skill retention, issues that we are currently addressing through other protocols.

Finally, the presented methodology represents a valuable tool for training which can also be applied at the postgraduate level to evaluate performance on both simulated and real procedures, such as endoscopies or clinical interviews, enhancing educational outcomes, on-site feedback and potentially improving clinical outcomes.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used the ChatGPT 4.0 commercial version as a complementary tool to assist in correcting the grammar of this manuscript. After using this tool, the authors reviewed and edited the content as needed, and the authors take full responsibility for the content and accuracy of the publication.

Supplementary Material

Note: To access the supplementary material accompanying this article, visit the online version of *Gastroenterology* at www.gastrojournal.org, and at https://doi.org/10.1053/j.gastro.2024.12.015.

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Conflicts of interest
These authors disclose the following: Julián Varas is the founder of Training Competence, an official spinoff startup of the Pontificia Universidad Católica de Chile. Gabriel Escalona is also affiliated with this spinoff. Training Competence develops educational web-based and mobile platforms, including the one used in this research. The remaining authors disclose no conflicts.

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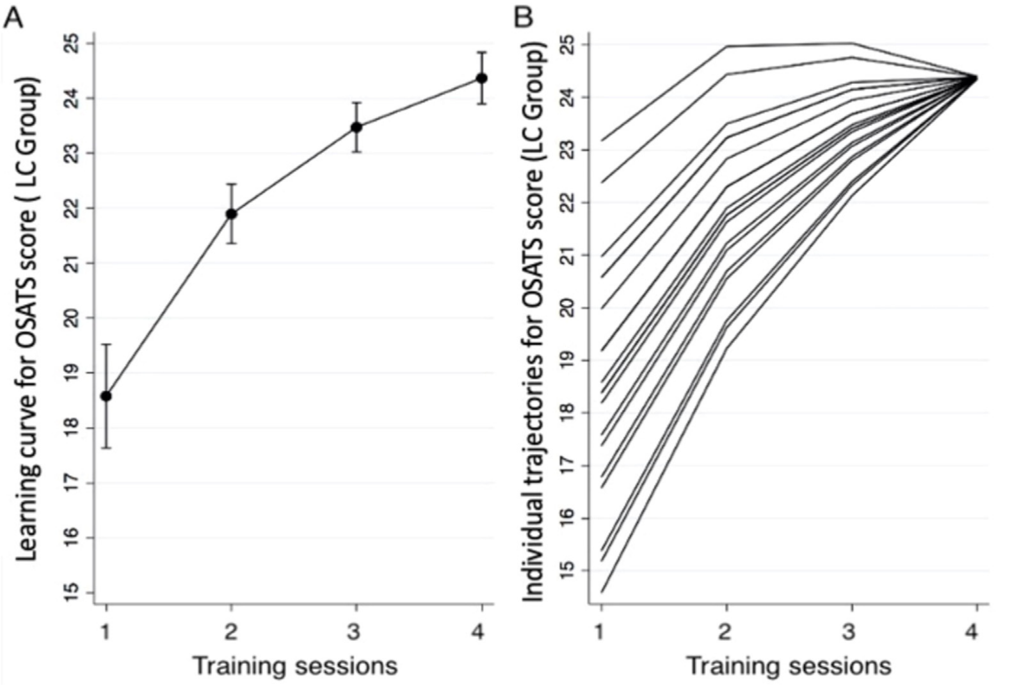

	Second Attempt in Simulated Scenario			Fourth Attempt in Simulated Scenario			Performance on Real Scenario (skill transfer on real patient)		
	PRS	OSATS	Time (min)	PRS	OSATS	Time (min)	PRS	OSATS	Time (min)
A	23	23	15.62	24	24	16.6	24	24	13.95
B	22	19	15.02	23	24	15.22	24	25	9.47
C	22	22	14.72	24	24	13.38	23	25	15.22
D	22	24	14.95	24	25	13.40	23	24	17.53
E	24	23	15.25	24	24	12.13	23	24	15.58

Supplementary Figure 1. Learning curves of the cohort trained face-to-face through a 4-session course. The table shows the transfer of skills: educational data from the 5 subjects that after completing this 4-session training underwent a real-patient assessment. OSATS, Objective Structured Assessment of Technical Skills; PRS, Procedure-Specific Rating Scale.

Supplementary Figure 2. Students', trainers', and faculty's perception of the course, cited text from surveys and focus groups. Organized using Kirkpatrick's framework. Adapted from: Kirkpatrick D, Kirkpatrick J. Evaluating training programs: the four levels. Oakland, CA: Berrett-Koehler Publishers, 2006.