# An Objective Assessment Tool for Basic Surgical Knot-Tying Skills

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**OBJECTIVE:** To determine if a knot-tying checklist can provide a valid score and if the checklist can be used by novice surgeons in a reliable manner.

**METHODS:** This study was conducted at the Surgical Skills Center at the University of California, San Francisco. A knot-tying checklist was developed from a kinesthetic knot-tying curriculum. Novice (67 first-year medical students) and experienced surgeons (8 residents postgraduate year 3 and higher and 2 attending physicians) were videotaped performing 4 knot-tying tasks, and the videotapes were rated with a global score and a checklist by interns ($n = 3$) and experienced ($n = 3$) surgeons.

**RESULTS:** Both interns and experienced surgeons can use the knot-tying checklist with acceptable reliabilities ($>0.8$ with 3 raters). The checklist is able to differentiate between novice and experienced surgeons, when used by both interns and experienced raters. The expert knot-tying score correlated with the global score overall ($r = 0.88$) and for each task ($r$ was 0.82 for task 1, 0.85 for task 2, 0.80 for task 3, and 0.81 for task 4).

**CONCLUSIONS:** The knot-tying checklist provides a valid score for basic surgical knot-tying and can be used by novice and experienced raters. Its use supports peer assessment of performance in a surgical skills laboratory setting. (J Surg 72:572-576. © 2015 Association of Program Directors in Surgery Published by Elsevier Inc. All rights reserved.)

**KEY WORDS:** knot tying, surgical skills, checklist, validated assessment, medical education

**COMPETENCIES:** Patient Care, Medical Knowledge, Practice-Based Learning and Improvement

## BACKGROUND

Surgical knot tying is the most fundamental of all basic skills. It is the first technical skill most trainees learn, and it is likewise the first skill on which they are judged in the operating room. Optimally preparing learners to perform basic surgical skills such as knot tying *in vivo* is an important goal of any basic surgical education program.[1] However, successful acquisition and refinement of technical skills requires deliberate practice and good feedback. Ideally, feedback provides the learner with a clear understanding of a goal and how to make progress toward that goal,[2] and it should be nonevaluative, supportive, timely, and specific.[3] The opportunities for feedback and practice in the operating room are limited for beginner surgeons.

Providing timely and specific feedback on basic skills even in the educational laboratory setting can be difficult and requires attending surgeons to set aside valuable time for teaching sessions.[4] If faculty are unavailable, they can review videotapes, but this reduces the timeliness and thus usefulness of feedback.[3] Finally, attending surgeons may actually have difficulty in providing specific feedback about a skill as basic as knot tying, because they are vulnerable to the expert blind spot.[5] Teaching and providing feedback may require a much more detailed conscious understanding of the task than most experts are able to access.

One way to overcome some of these constraints of feedback is to incorporate self-assessment and peer assessment. Self-assessment of technical skills has been shown to be unreliable,[6] but a checklist is helpful as it allows faculty to set clear expectations and the novice to focus on the details.[7] In addition to the increased availability of peers, peer assessment has other benefits in that teaching and critical assessment of peers stimulate insights and improvements in one's own work, especially if the assessment itself provides specific guidelines for refinements and can actually improve learning.[8] Self- and peer-assessments, especially when coupled with educator guidance, can be particularly beneficial because they emphasize the cooperative learning residents already practice in the hospital.[9]

Therefore, the purpose of this study was to determine if a checklist developed specifically for knot tying can provide a valid score and if the checklist can be used by novice

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surgeons in a reliable manner. If novice surgeons can reliably use the checklist, then they may be a resource for providing peer assessment and feedback.

The research questions assessed are as follows:

**(1)** How many raters and with what expertise are required for a reliable knot-tying score?
**(2)** Is there a significant difference in the performances of novices and senior learners based on the score from the knot-tying checklist?
**(3)** Is there an association of the score from the knot-tying checklist and a global rating provided by expert surgeons?

## METHODS

This was a psychometric study to determine the validity of the score from a novel checklist-style assessment tool for basic surgical knot tying. Validity evidence was collected according to its framing as a unitary construct.[10] The study received exempt status from the institutional review board. We recruited first-year medical students (who participated in the study as part of a "basic surgical skills" elective), surgical residents (postgraduate year 3 and higher), and attending surgeons. Participants were videotaped performing 4 different basic knot-tying tasks.

### Checklist

The knot-tying checklist was based on a successful approach to knot tying.[11,12] Although the traditional knot-tying curriculum illustrates the correct ways to orient, loop, and cinch the sutures to create secure knots,[13] it does not address the key *process* component that facilitates proper execution of those steps: manipulation of the suture to consistently obtain ideal relative lengths of the strands and maintain consistent tension on them. This kinesthetic handling of a suture is widely practiced by experts and is performed with specific, nonintuitive, maneuvers. Without explicit, declarative, instruction in these maneuvers, novices have great difficulty proceeding from the cognitive to the associative phase of skills acquisition.

This kinesthetic curriculum is based on several foundational principles, including (1) precise suture manipulation techniques (gathering, sliding, and locking suture), (2) obtaining and securing an optimal "working distance" 4 to 6 inches from the knot, and (3) precise understanding of knot conformation (precisely laying down knots as slip or square). An instructional video on the kinesthetic curriculum can be found on YouTube under "A Kinesthetic Curriculum for Teaching Knot Tying" by UCSF Skills Lab or at www.mededportal.org/publication/9328.[11]

The checklist based on these principles required completion of 4 tasks.

**(1)** *Tying at surface*: participants tied 6 throws on a Penrose drain attached to a tying board; they were allowed to throw hitches or square knots (5 items)
**(2)** *Tying at depth*: participants tied 6 throws on a hook inside a cup, designed to simulate "tying in a hole" in the operating room (5 items)
**(3)** *Atraumatic tying*: participants tied 6 throws onto a rubber band looped around a regular metal spoon, with the goal of not moving the spoon at all (5 items)
**(4)** *Square knot*: participants tied 6 throws on a Penrose drain attached to a tying board; knots had to lie down square (6 items)

The checklist is shown in the Figure. There were 21 items scored from 0 to 2.

### Global Rating

The global rating was an additional way to assess knot-tying abilities. The scale in this case was a visual analog scale from 0 to 100. Raters were asked to consider overall performance and likelihood of allowing this person to tie a knot in their operating room, with a high score indicating a more favorable rating. We required 3 raters to achieve reliability values exceeding 0.70 for each task (intraclass correlation coefficient for 3 raters: 0.82 (task 1), 0.85 (task 2), 0.70 (task 3), 0.71 (task 4), and 0.82 (overall).

Medical students, residents, and attending physicians were videotaped performing the 4 tasks described earlier. All participants had exposure to the kinesthetic curriculum before the videotaped sessions. Medical students completed the kinesthetic knot-tying curriculum as part of an elective. Resident participants had been taught by this approach as interns and reviewed the materials prior to their videotaped session. Attending physicians also reviewed materials before being videotaped.

All videos were deidentified. For each task, 3 surgeons reviewed the blinded videotapes and provided the global rating described earlier. An additional set of 3 surgeons scored the videotapes using the checklist; points were summed to create a score for each of the 4 tasks. Finally, 3 interns also scored a sample of the videotapes. This sample was selected to represent a range of knot-tying abilities.

To determine the interrater reliability for the checklist scores, intraclass correlation coefficients were calculated to determine the number of raters needed to obtain a reliable score. We averaged the global scores of the 3 reviewing surgeons to obtain a global rating per videotape reviewed. Two checklist scores also were calculated. One was the average of the 3 experts who rated the videotapes with the checklist and the other was the average of the 3 intern raters who performed the same rating procedure. We obtained checklist scores at the task level and also the total. To determine if the checklist score distinguished among levels of knot-tying expertise, we conducted a $t$ test comparing novice (medical students) and senior (residents and