Abstract

Background
Competency in surgical scrubbing, gowning and gloving (scrubbing-in) procedures is necessary to participate in surgery, but difficult for trainees to learn due to the fast pace of the operating room and limited availability of experts to provide training. Current methods of scrubbing-in procedures are antiquated. Simulation-based education aligns with the paradigm shift occurring in medical education as we transition from passive models. This study utilized the Delphi technique to identify necessary items to include in a scrubbing-in checklist that can be used in future simulation and assessment tools.

Methods
Surgeon experts participated in three rounds of a Delphi process. The panel consisted of surgical specialty residents, fellows and attending surgeons from gynecology, urology, general surgery, plastic, orthopedic and neurosurgery.

Results
From January 2018 to September 2018, 39 experts from 6 different surgical subspecialties participated in three Delphi survey rounds. Of the 43 items identified during the first round, 30 (70%) resulted with an importance rating $\geq 4.0$. During the final round, a consensus of $\geq 85\%$ was reached for 22 total items (73%).

Conclusion
We developed a 22-step checklist for scrubbing-in procedures utilizing the Delphi technique. This checklist will enhance undergraduate medical education simulation curriculums and assessments.

Keywords: Feedback; Education environment; Surgery; Medical education research; Undergraduate
Introduction

Surgical scrubbing, gowned, and gloving are integral skills necessary to participate in surgery. However, these skills are difficult for medical trainees to learn due to the fast pace of the operating room (OR), and the limited time and availability of expert medical professionals to provide training. Further compounding these barriers are ineffective teaching methods and the pressure of increased risk to patients due to the inherent high stakes environment of the OR (Park et al., 2007; Pirie, 2010b; Pirie, 2010a; Samia et al., 2013). Such factors impede skill acquisition by trainees and the general workflow in the operative arena (Park et al., 2007; Samia et al., 2013).

Current methods of teaching scrubbing, gowned, and gloving procedures include detailed written protocols, videos of the process, and formal instruction prior to clinical rotations (Pirie, 2010b; Pirie, 2010a; Nurses, 2019). There is no standardized assessment for this skill and it is not included in the national practical assessment for medical students provided during medical school clerkships. The skill is also not included in the Step 2 Clinical Skills, an exam that assesses national standards of competency and basic patient-centered skills that underlie safe and effective practice of medicine (Examination, 2019). Passive methods of teaching and deficiencies in assessment tools translate to poor learning of fundamental OR procedures. While some operating rooms employ staff to teach students scrubbing techniques prior to clinical rotations, there is no opportunity to assess the students understanding after the one-time training session. These factors lead to many students experiencing significant amounts of stress in the operating room which also impacts learning (Kanumuri et al., 2008; Samia et al., 2013; Hampton et al., 2015).

Simulation improves surgical skills such as laparoscopy and endoscopy (McDougall, 2007; Kanumuri et al., 2008; Schout et al., 2010; Beyer et al., 2011; Sedlack, 2013; Singh et al., 2015). Based on feedback from students, providing a simulation prior to the first OR experience gives students increased confidence and comfort (Sperling, Clark and Kang, 2013; Mohan et al., 2015; Barnum et al., 2017). Data shows that medical students who participate in simulated activities have more opportunity to engage actively with OR procedures during a clerkship and have more confidence when they are performing those activities in the OR (Dayal et al., 2009). Simulation-based education aligns with the paradigm shift occurring in medical education as we transition from antiquated models.

Prior to developing simulation or assessment tools, the content that underlies the training must be formulated. Few studies to date analyze procedures specific to scrubbing, gowned, and gloving (Pirie, 2010b; Barnum et al., 2017; Jeyakumar, Sabu and Segeran, 2017). Further, published research lacks methodologic rigor when describing the development of procedural checklists (Pirie, 2010b; Pirie, 2010a). Medical simulation allows the acquisition of clinical skills through deliberate practice rather than apprentice-like, passive styles of learning. Once created, a reliable and validated checklist can be incorporated into simulation curricula and clerkship Objective Structured Clinical Examinations (OSCEs) to assess competency in this necessary skill. Our study addresses this gap in undergraduate medical education via the use of the Delphi technique to identify necessary items to include in a checklist for surgical scrubbing, gowned, and gloving that can be used in a future simulation and assessment tools.

Material and Methods

This IRB-approved study was conducted at an academic, tertiary care institution.

Questionnaire Development

Questionnaire development was conducted by a panel of two facilitators, an expert minimally invasive gynecological surgeon (ND) and a third-year medical student (SC).

Panel of Experts
From January 2018 to September 2018, 29 experts were asked to participate in up to three rounds of a Delphi survey process. The panel consisted of surgical specialty senior residents (PGY4 or older), fellows and attending surgeons from gynecology, urology, general surgery, plastic surgery, orthopedic surgery and neurosurgery. (Table 1) Panelists volunteered for the study and gave written consent to study participation at time of the first survey response.

**Table 1: Surgical specialty distribution across Delphi rounds.**

| Surgical Specialty | Round 1 | Round 2 | Round 3 |
|--------------------|---------|---------|---------|
| Orthopaedic        | 1       | 1       | 0       |
| Urology            | 1       | 1       | 2       |
| Gynecology         | 6       | 17      | 19      |
| General Surgery    | 1       | 4       | 3       |
| Plastic            | 0       | 5       | 4       |
| Neurosurgery       | 0       | 1       | 0       |
| TOTAL              | 9       | 29      | 28      |

**Delphi Process**

The Delphi technique is a procedure that uses a series of questionnaires to obtain a consensus among experts about items to be included in a study or tool, particularly in areas where there is little to no evidence (Campbell and Cantrill, 2001). This methodology has been widely used in areas of healthcare such as medical education and improving clinical practice (Alahlafi and Burge, 2005; Ferri et al., 2005). This study used a three-round Delphi technique to obtain consensus on the scrubbing, gowning and gloving process. (Figure 1)

**Figure 1.** Three-round modified Delphi technique used in study.

The first round survey asked experts to list in narrative form the discrete steps necessary for surgical scrubbing, gowning and gloving. There was no limit to the number of items that could be suggested.

The items suggested by more than one expert in the first round were then used to develop the second round survey. A tally of the number of first round experts that suggested a specific item were included in this survey. The experts participating in the second round rated each item on a 5-point Likert scale (1 equals not important and 5 indicates very important). Average Likert scale scores were calculated for each item and those with a mean importance of ≥ 4.0 were included in the third round (Neveu et al., 2017; Francis et al., 2018).
The third round survey included items that had ≥ 80% agreement (mean importance of ≥ 4.0 out of 5) from the second round with means, standard deviations, percent of ratings that were equal to 4, and percent of ratings that were equal to 5 provided for each item. Experts voted to include or exclude each item in the survey. There is no universally agreed proportion for consensus but benchmarks ranging from 75-90% are commonly reported (Diamond et al., 2014; French et al., 2017; Neveu et al., 2017). We defined a consensus regarding a specific item ≥ 85% agreement (i.e., a rating of 8.5–10). Items with a consensus of ≥ 85% were selected for the final checklist.

Results

Delphi Procedure

Figure 2 provides an overview of the three rounds of surveys included in our Delphi process.

Figure 2. Delphi process flowchart for study.
Experts
A total of 39 surgeons representing six different surgical subspecialties were recruited. (Table 1) Nine out of 10 invited experts participated in the first round, 29 of 32 invited experts participated in the second round and 28 of 32 invited experts participated in the third round.

First Round
A total of 133 items were suggested. Forty-three items were suggested by more than one expert and thus the remaining 90 items were excluded.

Second Round
The forty-three items from the first round were redistributed to twenty-nine experts. Twelve of twenty scrubbing items had a mean consensus importance rating of \( \geq 4.0 \). Eighteen of the twenty-three defined gowning and gloving items had a mean consensus importance rating of \( \geq 4.0 \). Thirty total items (70\%) resulted with an importance rating \( \geq 4.0 \). (Table 2)

**Table 2: Results of Delphi Survey.**

| Items                                                                 | Round 2 | Round 3 |
|----------------------------------------------------------------------|---------|---------|
|                                                                      | Mean    | STD     | % > 4 | % > 5 | % Agreement (\( \geq 4 \)) | Selection | Selection |
| Remove all jewelry                                                   | 4.6     | 0.87    | 0.21  | 0.72  | 93.10                       | Included   | Included  |
| Approach scrub sink                                                  | 3.3     | 1.67    | 0.10  | 0.41  | 51.72                       | X          | X         |
| Put on face mask                                                     | 4.7     | 0.53    | 0.21  | 0.76  | 96.55                       | Included   | Included  |
| Turn on scrub sink water                                             | 4.2     | 1.15    | 0.17  | 0.59  | 75.86                       | Included   | X         |
| Grab a pre-package scrub/nail kit                                    | 4.3     | 1.03    | 0.21  | 0.59  | 79.31                       | Included   | Included  |
| Open kit                                                            | 3.7     | 1.69    | 0.14  | 0.55  | 68.97                       | X          | X         |
| Apply water to sponge side of brush                                  | 3.9     | 1.19    | 0.28  | 0.41  | 68.97                       | X          | X         |
| Moisten hands and arms under the water without touching the faucet   | 4.6     | 0.56    | 0.31  | 0.66  | 96.55                       | Included   | Included  |
| Use nail file to clean under each nail                               | 3.7     | 1.37    | 0.17  | 0.41  | 58.62                       | X          | X         |
| Use firm/bristled side of brush to scrub nails                       | 4.2     | 1.10    | 0.28  | 0.52  | 79.31                       | Included   | Included  |
| Throw away nail file                                                 | 2.5     | 1.60    | 0.10  | 0.21  | 31.03                       | X          | X         |
| Use firm/bristled end of scrub brush to scrub all surfaces of fingers| 4.6     | 0.74    | 0.28  | 0.66  | 93.10                       | Included   | Included  |
| Use sponge to scrub the entire length of forearm, starting most distal (wrist) to elbow | 4.7     | 0.45    | 0.28  | 0.72  | 100.00                      | Included   | Included  |
| Switch scrubber to clean hand                                         | 4.2     | 1.28    | 0.21  | 0.59  | 79.31                       | Included   | X         |
| Use sponge to scrub entire length of contralateral forearm, starting most distal (wrist) to elbow | 4.7     | 0.54    | 0.24  | 0.72  | 96.55                       | Included   | Included  |
| Throw out sponge                                                     | 2.9     | 1.49    | 0.07  | 0.24  | 31.03                       | X          | X         |
| Rinse off both arms                                                  | 4.7     | 0.53    | 0.21  | 0.76  | 96.55                       | Included   | Included  |
| Turn off water                                                       | 2.5     | 1.45    | 0.03  | 0.17  | 20.69                       | X          | X         |
| Proceed to OR                                                        | 3.7     | 1.62    | 0.07  | 0.55  | 62.07                       | X          | X         |
| Use back/butt/hip to enter OR                                         | 4.5     | 1.09    | 0.14  | 0.76  | 89.66                       | Included   | Included  |
| Enter OR with elevated hands/arms taking care to avoid touching anything | 4.7     | 0.59    | 0.14  | 0.79  | 93.10                       | Included   | Included  |
| Approach | Scrub Tech/Nurse with Elevated Hands/Arms | Score | Complexity | Frequency | Included/Directed | X | X |
|----------|------------------------------------------|-------|------------|-----------|------------------|---|---|
| Hold out one hand to accept a dry towel from scrub tech/nurse | 4.2 | 0.80 | 0.45 | 0.38 | 82.76 | Included | Included |
| Dry opposite hand/arm using the hand the towel was placed in | 4.3 | 0.60 | 0.55 | 0.38 | 93.10 | Included | Included |
| Grasp the opposite side of the towel with dry hand | 4.1 | 0.92 | 0.38 | 0.41 | 79.31 | Included | X |
| Flip towel over so that the unused portion of towel is exposed | 4.1 | 0.92 | 0.38 | 0.41 | 79.31 | Included | X |
| Dry opposite hand/arm that has not yet been dried | 4.1 | 0.76 | 0.52 | 0.31 | 82.76 | Included | Included |
| Discard towel | 2.9 | 1.33 | 0.14 | 0.17 | 31.03 | X | X |
| Wave arms back and forth small amount to finish off drying process | 2.1 | 1.08 | 0.07 | 0.03 | 10.34 | X | X |
| With scrub tech/nurse holding gown open, place both hands/arms into sleeves | 4.4 | 0.86 | 0.24 | 0.59 | 82.76 | Included | Included |
| Distance self from sterile equipment | 4.1 | 1.27 | 0.17 | 0.59 | 75.86 | Included | X |
| Allow nonsterile nurse/circulator to tie up back of gown | 4.3 | 0.81 | 0.24 | 0.55 | 79.31 | Included | Included |
| With left hand still protected in the gown sleeve, gently pull back right sleeve to slightly expose fingertips | 4.1 | 0.92 | 0.38 | 0.38 | 75.86 | Included | X |
| With scrub tech/nurse holding right glove open, put hand into right glove | 4.7 | 0.54 | 0.24 | 0.72 | 96.55 | Included | Included |
| Use gloved hand to pull left sleeve back to slightly expose 5 fingertips | 4.2 | 0.85 | 0.38 | 0.41 | 79.31 | Included | X |
| With scrub tech/nurse holding left glove open, put left hand into glove | 4.5 | 0.91 | 0.21 | 0.69 | 89.66 | Included | Included |
| Once gloves are on, pull back sleeves of gown | 3.0 | 1.22 | 0.24 | 0.10 | 34.48 | X | X |
| Free cord from gown using the attached card | 3.9 | 1.18 | 0.41 | 0.34 | 75.86 | X | X |
| Hand card to scrub tech/nurse or circulator | 4.1 | 0.92 | 0.38 | 0.38 | 75.86 | Included | Included |
| Rotate in gown with scrub tech/nurse or circulator still holding card | 4.6 | 0.63 | 0.31 | 0.62 | 93.10 | Included | Included |
Regrasp the tie from the scrub tech/nurse or circulator

|  | 4.2 | 0.91 | 0.41 | 0.45 | 86.21 | Included | Included |
|---|---|---|---|---|---|---|---|

| Tie both ties of gown together | 4.4 | 0.94 | 0.28 | 0.59 | 86.21 | Included | Included |
|---|---|---|---|---|---|---|---|

| Approach sterile field | 3.7 | 1.51 | 0.07 | 0.52 | 58.62 | X | X |

**Bold** indicates 30 items with a Likert scale importance > 4.0

‘X’ indicates an item that was deleted

### Third Round

The thirty items from the second round with a mean Likert scale importance ≥ 4.0 were presented to twenty-eight experts. A consensus of ≥ 85% was reached for twenty-two total items (73%), ten items for scrubbing and twelve for gowning and gloving. The final twenty-two-item checklist is shown in Table 3.

### Table 3: Final Scrubbing, Gowning, and Gloving Checklist.

| SCRUBBING |
|---|
| 1. Remove all jewelry |
| 2. Put on face mask |
| 3. Grab a pre-package scrub/nail kit |
| 4. Moisten hands and arms under the water without touching the faucet |
| 5. Use firm/bristled side of brush to scrub nails |
| 6. Use firm/bristled end of scrub brush to scrub all surfaces of fingers |
| 7. Use sponge to scrub the entire length of forearm, starting most distal (wrist) to elbow |
| 8. Use sponge to scrub entire length of contralateral forearm, starting most distal (wrist) to elbow |
| 9. Rinse off both arms |
| 10. Use back/butt/hip to enter OR |

| GOWNING AND GLOVING |
|---|
| 11. Enter OR with elevated hands/arms taking care to avoid touching anything |
| 12. Hold out one hand to accept a dry towel from scrub tech/nurse |
| 13. Dry opposite hand/arm using the hand the towel was placed in |
| 14. Dry opposite hand/arm that has not yet been dried |
| 15. With scrub tech/nurse holding gown open, place both hands/arms into sleeves |
| 16. Allow nonsterile nurse/circulator to tie up back of gown |
| 17. With scrub tech/nurse holding right glove open, put hand into right glove |
| 18. With scrub tech/nurse holding left glove open, put left hand into glove |
| 19. Hand card to scrub tech/nurse or circulator |
| 20. Rotate in gown with scrub tech/nurse or circulator still holding card |
| 21. Regrasp the tie from the scrub tech/nurse or circulator |
| 22. Tie both ties of gown together |

### Discussion

We created a surgical scrubbing, gowning and gloving checklist utilizing the Delphi method. This tool will inform simulation curricula and OSCEs for surgical scrubbing, gowning and gloving skills and techniques. To our knowledge, this is the first study to provide an agreed consensus on the content of a checklist for scrubbing, gowning, and gloving procedures.
There are few learning resources for these procedures and of those available, many are inaccessible and not evidence-based. The Association of periOperative Registered Nurses (AORN) provides guidelines and modules for scrubbing, gowning and gloving but the references are only accessible via paid-membership (Nurses, 2019). Videos and written protocols are available via public domains, but none are consensus-driven or evidenced-based. Pirie et al. provide a 6-step hand washing and gowning and gloving method. The hand washing, however, is not relevant for surgical scrubbing and discrete steps are not provided for gowning and gloving. (Pirie, 2010a; Pirie, 2010b). If these processes are performed incorrectly or inefficiently, it can lead to an overall experience that is intimidating, humiliating, and most importantly unproductive for undergraduate medical students in the operating theatre (P. M. Lyon, 2003; P. Lyon, 2004). The increased stressors in combination with the current lack of resources thereby underscore the need for a such a validated checklist.

In addition to limited resources, the available passive methods of teaching do not translate to effective practice in the real-world setting. Posner's theory of motor skill acquisition supports the implementation of simulation technology in the training of technical procedures (Posner, 1965). This theory defines three stages of transition from novice to expert: cognitive stage, integrative stage, and autonomous stage. Initially, learners intellectualize the task and serialize the steps. Then, knowledge, practice, and feedback are rendered into appropriate motor execution. Lastly, the performance becomes smoother motor control that allows for attention to be shifted to other aspects of the procedure (Posner, 1965). Based on Posner's theory, simulation technology can serve as a powerful tool in medical education, but it is only effective with the foundation of strong, proven pedagogy. The consensus-based checklist generated in this study can serve as a component of this foundation.

The Delphi method is a rapid, inexpensive, and validated technique for obtaining expert consensus about a topic where little evidence exists (Goodman, 1987). Specifically, the Delphi method allows participants reach an agreement without the need to be in the same room and minimizes potential group think. There are inherent limitations to the use of the Delphi method and this study. The selection of experts is a critical issue due to the dependence of the Delphi method on the quality of the panel. Our panel consisted of senior residents, fellows and attending physicians with extensive experience in surgical procedures and surgical teaching. All panel members work in university hospitals and actively participate in training medical students and junior residents. Some expert panelists were lost to follow-up between rounds due to availability, however the response rate was high compared to similar studies likely. In the Delphi method, the contribution of the facilitators on the data collection could arguably dilute the original content. The facilitators of this study aimed to reduce redundancy by combining and clarifying items, and made every effort in preserving the essential, core content provided by the panel.

Another limitation of this study is that all of the faculty are from a single institution with the majority from the obstetrics and gynecology department. Some institutions have unique requirements that are specific to their operating room. While, this may hinder the generalizability, the skill of scrubbing-in is not specific to specialty or institution. It is fundamental for every surgeon physician and personnel that intends to participate in sterile operating room procedures. This checklist is not intended to provide a one-size-fits all protocol, but instead provide a foundational competency tool for sterile scrubbing-in.

Overall, the development of our scrubbing, gowning, and gloving checklist can serve as an important tool for medical education evaluation, specifically at the undergraduate medical education level. Evidence confirms the increased need for clinical proficiency among medical graduates (Mukhopadhyay and Smith, 2010). An increasing number of students are completing medical school with the theoretical knowledge but lacking clinical skills necessary for real-world practice. In a more traditional system, this lack of practical skill was accepted and reserved for graduate medical education. However, with the revolution of technology, medical students now have the opportunity to be develop competency in clinical skills such scrubbing-in, insertion of a nasogastric tube or
intravenous catheter placement. Medical schools across the country have endorsed efforts to enhance clinical skills acquisition (Al-Elq, 2010; Mukhopadhyay and Smith, 2010). To address this, such a validated checklist, can be incorporated into surgical OSCEs to test skill acquisition and demonstrate proficiency prior to medical school graduation.

Future directions of this study include validity and reliability studies of the checklist. We will conduct an IRB-approved study to videotape medical students, residents and fellows at various stages in training, and evaluate their performance using the checklist. We hypothesize that the tool will be able to detect a difference in surgical scrupbing, gowning and gloving skills between pre-clinical medical students and students who have completed their clinical clerkships. Ultimately, we aim to use the validated checklist in two domains. The first is to guide development of a simulation-based training system to teach surgical scrubbing, gowning and gloving prior to exposing learners to the operating room. Secondly, a reliable and validated checklist can be incorporated into medical education curriculums to evaluate clinical competencies.

**Conclusion**

We used the Delphi method to develop a twenty-two item checklist for surgical scrubbing, gowning, and gloving. Research assessing the reliability and validity of our checklist is ongoing after which the checklist can be incorporated into undergraduate medical education simulation curriculum and assessment. Future goals include utilizing the checklist to build an augmented reality training model for surgical scrubbing, gowning and gloving.

**Take Home Messages**

- Scrubbing, gowning, and gloving (ie, "scrubbing-in") procedures are difficult for medical trainees to learn due the fast pace of the operating room and current limited educational tools.
- To date, there is a lack of consensus for proper scrubbing-in procedures.
- The Delphi method can be used to develop expert consensus for simulation-based training of technical procedures.
- This paper describes the use of the Delphi method to develop a checklist of key steps in surgical scrubbing, gowning, and gloving.
- This checklist will be able to inform undergraduate medical education simulation curriculums and assessments.

**Notes On Contributors**

**Stephen Canton** is a fourth-year medical student at University of Pittsburgh School of Medicine. His research interests include the use of augmented/virtual reality to improve intraoperative outcomes, patient reported outcomes, and surgical education. After medical school, he will pursue residency in Orthopaedic surgery with a focus on trauma surgery. ORCiD: [https://orcid.org/0000-0002-9928-575X](https://orcid.org/0000-0002-9928-575X)

**Christine Foley** is a second-year fellow in minimally invasive gynecologic surgery at Magee-Womens Hospital. Her research interests include surgical education curriculums and patient reported outcomes. After fellowship, she is joining the faculty at Women and Infants Hospital with an appointment as Assistant Professor at Brown University School of Medicine. ORCiD: [https://orcid.org/0000-0002-1144-2686](https://orcid.org/0000-0002-1144-2686)
Nicole Donnellan is a minimally invasive gynecologic surgeon (MIGS), assistant residency program director (PD) and associate PD of the fellowship in MIGS at Magee-Womens Hospital. She is a course director for the medical school Reproductive Biology course. At the residency level, she has developed and refined the laparoscopic simulation curriculum. ORCiD: https://orcid.org/0000-0001-9872-0249

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Figure 1. Source: the author.

Figure 2. Source: the author.

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**Appendices**

None.

**Declarations**

*The author has declared that there are no conflicts of interest.*

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**Ethics Statement**

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