INSTRUCTIONAL DESIGN AND ASSESSMENT

Comparison of Aseptic Compounding Errors Before and After Modified Laboratory and Introductory Pharmacy Practice Experiences

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Objective. To determine whether aseptic compounding errors were reduced at the end of the third professional year after modifying pharmacy practice laboratories and implementing an institutional introductory pharmacy practice experience (IPPE).

Design. An aseptic compounding laboratory, previously occurring during the third-year spring semester, was added to the second-year spring semester. An 80-hour institutional IPPE was also added in the summer between the second and third years. Instructors recorded aseptic compounding errors using a grading checklist for second-year and third-year student assessments. Third-year student aseptic compounding errors were assessed prior to the curricular changes and for 2 subsequent years for students on the Oklahoma City and Tulsa campuses of the University of Oklahoma.

Assessment. Both third-year cohorts committed fewer aseptic technique errors than they did during their second years, and the probability was significantly lower for students on the Oklahoma City campus. The probability of committing major aseptic technique errors was significantly lower for 2 consecutive third-year cohorts after the curricular changes.

Conclusion. The addition of second-year aseptic compounding laboratory experiences and third-year institutional IPPE content reduced instructor-assessed errors at the end of the third year.

Keywords: Aseptic compounding, introductory pharmacy practice experience, institutional practice, hospital practice

INTRODUCTION

All pharmacy students are required to take introductory and advanced pharmacy practice experiences (IPPE and APPE, respectively) in institutional settings according to Accreditation Council for Pharmacy Education Accreditation Standards.¹ The current standards further define that a minimum of 75 IPPE hours are required in institutional settings. Although challenges to providing a sufficient number and quality of experiences in institutional practice exist,² collaborations between academia and health care institutions to align IPPE and APPE competencies can benefit both parties.

One example is sterile product compounding. Suggested entry-level practice competencies for institutional practice include the demonstration of aseptic technique to provide sterile compounded parenteral solutions.³ The

United States Pharmacopeia (USP) 797 provides detailed guidance on the conditions and practices to prevent microbial contamination of sterile compounded products in pharmacy practice, including direct observation of aseptic compounding skills and media-fill testing to demonstrate absence of microbial growth in parenteral products.⁴

Pharmaceutical compounding, whether sterile or nonsterile, is a skill requiring significant practice and repetition to demonstrate competency. The scope, frequency, timing, and methods by which schools and colleges of pharmacy implement aseptic technique curricula are specific to each professional program. Models for delivering content and assessing aseptic compounding techniques of pharmacy students are published.⁵⁻⁷ Patel et al described the use of virtual technology in a one-semester parenteral products course as a teaching method to impart knowledge and application of aseptic procedures and USP 797 regulations.⁵ This study showed a significant ($p < 0.001$) improvement in written examination scores 2 years after implementation but did not include a laboratory component to directly assess aseptic technique of pharmacy

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students. Brown et al described implementation of a scoring rubric for aseptic technique over a 2-semester, second professional year course in which students compounded 11 parenteral products during 8 laboratory sessions occurring approximately every 4 weeks.⁶ In comparison to a baseline assessment, formal evaluation of student aseptic technique showed significant ($p < 0.001$) decreases in potentially harmful errors at the end of the fall and spring semesters, though “manipulation of materials” and “working in airflow” were still areas in need of improvement for many students at the end of the course. This study provided detail on the nature of errors by pharmacy students as assessed by instructors in real time, though the investigators did not include media-fill testing to determine the presence of microbial contamination in prepared products. Isanhardt et al used media-fill testing prior to and at the end of a one-semester parenteral product laboratory course to assess aseptic technique competency for second-professional year students.⁷ During this one-semester course, each student attended 14 weekly 2-hour laboratory sessions and prepared at least 28 parenteral products. For the 2 media-fill assessments, each student prepared 3 low-risk and 3 medium-risk syringes. The overall microbial contamination rate was significantly ($p < 0.001$) decreased from 4.2% at baseline to 0% of syringes at the end of the course. Direct visual instructor observation and assessment of student aseptic technique also were mentioned for this study. However, specific details were not provided, and a correlation of observed student errors with actual contamination of syringes apparently was not completed.

Aseptic technique curricula should provide pharmacy students with sufficient baseline training to safely contribute to this area of pharmacy practice on their IPPE and APPE rotations. Students should ultimately gain the proficiency needed by practicing pharmacists in settings where parenteral products are prepared. Studies involving instructor assessment of aseptic compounding skills were limited to one⁷ or 2 semesters,⁶ though retention of compounding skills for nonsterile products significantly ($p < 0.001$) diminishes if not practiced for 12 months.⁸ Investigating models of delivering and/or repeating aseptic technique curricula over longer periods of time and evaluating the effect of intervening IPPEs on student skills in aseptic compounding may be beneficial areas of study.

We implemented a curriculum modification that incorporated aseptic compounding into the second professional and third professional years (instead of only the third year), as well as an institutional IPPE during the summer term between these years. The objectives of this study were to determine if curriculum changes regarding sterile compounding influenced the number of

compounding errors detected by faculty graders for students at the completion of their third professional year compared with errors detected at the end of their second professional year; to compare the number of aseptic technique compounding errors made by third-year professional students completing the new compounding curriculum with those of third-year students who did not; and to determine whether the assigned practice site for the summer institutional IPPE and/or “hospital experience” documented at the beginning of the second year had any influence on the occurrence of errors at the end of the third year.

The structure and details of our aseptic compounding curriculum during both professional years is described, including use of online teaching media, compounding practice protocols with instructor feedback, and terminal assessment methods of student aseptic technique. The discussion includes additional findings from relevant publications of aseptic compounding specific to pharmacy students, as well as details from studies examining personnel and environmental factors affecting product sterility in actual practice environments.

DESIGN

A quasi-experimental pre/posttest study design was used. The second and third years of the professional curriculum were modified: aseptic compounding was incorporated into the second year (instead of only the third year), and a 2-week, 80-hour institutional IPPE was added in the summer between the second and third years. Learning objectives for the institutional IPPE included demonstration of proper aseptic technique and preparation of sterile parenteral solutions. Additionally, formative assessment and reflective journaling exercises were included as part of the development of these competencies.

A required summative assessment of student performance was conducted by supervising preceptors at the end of the institutional IPPE. Institutional IPPE placements were determined by student preferences. Across the 2 cohort years assessed (classes of 2014 and 2015), 23 to 25 institutional sites were used for the summer institutional IPPEs, with students being assigned to one of the 7 available 2-week summer time blocks. The number of students assigned to the same IPPE site varied from 1 to 15, with an average of 4.5 students per site.

Prior to the 2011-2012 academic year, terminal preparatory aseptic compounding content and laboratories had occurred during the third-year spring semester, immediately prior to the fourth professional APPE year. In preparation for implementation of the third-year 80-hour summer institutional IPPE, additional aseptic

compounding laboratory experiences were added to the second-year spring semester to better support basic skill development.

For the study period, students in the second and third years reviewed sterile product course materials and viewed online aseptic compounding video segments outside of class prior to scheduled laboratory sessions (Table 1). Second-year students were instructed to review 11 video segments, totaling 44 minutes. Third-year students were required to review the same 11 video segments and an additional 8 video segments of 25 minutes for a total video content of approximately 69 minutes.

All students had unlimited online access to these video segments, which were internally produced for demonstration of desired aseptic compounding techniques. During 40-minute time blocks, second-year students completed one laboratory compounding protocol consisting of 9 low-risk aseptic technique manipulations preparing small volume parenteral products with a single additive of various volumes. Third-year students completed 2 such laboratories with small volume parenteral products for a total of 16 low-risk aseptic technique manipulations, in addition to receiving experience working with filters, transfer needles, and ampules. Second-year

and third-year students received formative feedback at a maximum ratio of 1 instructor to 2 students during their laboratory sessions prior to their final aseptic technique assessments.

For final assessments, students individually prepared a simulated small volume parenteral product with a single additive while an instructor rated aseptic technique performance and made note of errors via a checklist (Appendix 1). Major errors were those considered to have the potential to compromise product sterility, such as directly touching sterile sites, not disinfecting sterile sites, obstructing sterile airflow to sterile sites, or exposing sterile sites to nonsterile airflow during compounding. Minor errors included all other technique-related items not deemed to have high potential to directly compromise product sterility. Faculty instructors and/or pharmacy practice resident instructors provided formative feedback during the preparatory laboratory sessions, and faculty instructors made the final aseptic technique assessments at the end of the second-year and third-year spring semesters.

A comparison of major and minor aseptic technique errors between the second and third years occurred for

Table 1. Sterile Product Course Content Delivery

Sterile Product Topic (video time)	Content	Second Year Spring	Third Year IPPE	Third Year Spring
Parenteral nutrition/calculations	Text	✓	✓	✓
Sterile products, USP 797	Text	✓	✓	✓
Drug incompatibilities/instability	Text	✓		✓
General rules for aseptic compounding	Text	✓		✓
Laminar airflow theory/critical sites (3:25)	Text/Video	✓		✓
Contamination models (2:42)	Text/Video	✓		✓
Barrier controls (2:35)	Text/Video	✓		✓
Cleaning a horizontal hood (4:14)	Text/Video	✓		✓
Staging materials (4:37)	Text/Video	✓		✓
Assembling a needle and syringe (1:48)	Text/Video	✓		✓
Withdrawing fluid from a vial (5:35)	Text/Video	✓		✓
Reconstituting a powder (2:33)	Text/Video	✓		✓
Injecting into an end-type port (2:27)	Text/Video	✓		✓
Injecting into a belly-type port (1:57)	Text/Video	✓		✓
Common errors to avoid (15:41)	Video	✓		✓
Withdrawing fluid from an ampule (4:01)	Text/Video			✓
Inserting an administration set (2:42)	Text/Video			✓
Assembling filters to a syringe (3:57)	Text/Video			✓
Using a transfer needle (2:33)	Text/Video			✓
Reconstitution via transfer needle (4:15)	Text/Video			✓
V-grip techniques (2:24)	Video			✓
Bubble extraction techniques (2:10)	Video			✓
Ampule techniques (3:13)	Video			✓

IPPE=introductory pharmacy practice experience; USP=United States Pharmacopeia

2 consecutive student classes (class of 2014 through the class of 2015) after the curricular change. The analyses were conducted using data from 2 time points: the end of the second year immediately prior to the summer 80-hour institutional IPPE and the end of the third year, when all aseptic compounding content had been delivered/assessed.

Aseptic technique compounding errors of students completing the curriculum prior to the curricular change (class of 2013) were compared with those of students who completed the new curriculum (classes of 2014 and 2015). While controlling for institutional IPPE site clustering (ie, students nested within IPPE sites), the effects of campus location (Oklahoma City or Tulsa) and hospital experience on the measures of association between aseptic technique compounding errors among the 3 student cohorts were examined. This study was approved by the institutional review board for the University of Oklahoma Health Sciences Center.

EVALUATION AND ASSESSMENT

Table 2 summarizes the prevalence of minor and major aseptic technique compounding errors by cohort, campus, and experience working as an intern in hospital practice. A proportional odds (or ordinal logistic) regression model^{9,10} was used to examine whether the probability of aseptic compounding errors decreased after the implementation of curriculum changes (pre/post comparisons) among pharmacy students and whether these changes in the probability of aseptic compounding errors were modified by student cohort, campus location, and previous hospital experience. The proportional odds model was deemed appropriate based on the chi-square

score test of the proportional odds assumption using pre-assessment ($\chi^2=5.11$, $df=2$, $p=0.08$) and postassessment ($\chi^2=2.09$, $df=2$, $p=0.35$) data.

Our outcome of interest (dependent variable) was ordinal defined by 4 levels on a continuum from: no error (0), minor error (1), major error (2), and minor plus major error (3). The “no error” level was used as the outcome reference category in all proportional odds regression models examined. A likelihood ratio-based test¹¹ was used to test the null hypotheses that: (1) there was no variability in the probability of committing an error (random intercept terms) and (2) there was no variability in the probability (random slope terms) of committing an error among students nested within practice sites over time.

There was no evidence of student-to-student variability or IPPE site variability regarding the probability of committing an aseptic compounding error at baseline or over time (pre/post curriculum changes), based on the results from likelihood ratio tests for student/IPPE site variability ($p>0.05$). Therefore, student, cohort, time (pre/post), campus, and second-year hospital experience, and their interaction (eg, cohort x time x campus/hospital experience) effects were modeled as fixed effects.

There was no missing data for any of the investigated covariates or student error assessments during the second or third years of pharmacy school. Parameter estimates (odds ratios) were generated using maximum likelihood procedures. Significance of all statistical tests were assessed at a Type I error rate (α) of 0.05.

To determine whether the pre/post probability of committing an error varied across cohort groups and whether these changes were modified by campus or

Table 2. Summary of the Percentage of Pharmacy Students with Minor and/or Major Aseptic Technique Compounding Errors by Cohort, Campus, and Hospital Work Experience

Variable	Cohort 2013 ^{a,d}			Cohort 2014 ^{b,d}						Cohort 2015 ^{c,d}					
	Third Year (% students)			Second Year (% students)			Third Year (% students)			Second Year (% students)			Third Year (% students)		
	M ₁	M ₂	M ₁₂	M ₁	M ₂	M ₁₂	M ₁	M ₂	M ₁₂	M ₁	M ₂	M ₁₂	M ₁	M ₂	M ₁₂
All Students	28	29	6	30	21	10	22	11	5	41	13	13	20	8	9
Tulsa	23	16	0	25	22	0	6	19	6	48	0	13	13	3	13
Oklahoma City	30	34	8	32	22	14	28	8	4	38	18	13	24	10	7
Hospital experience															
No	26	29	6	29	24	9	24	10	5	41	12	12	23	8	7
Yes	50	25	0	38	8	15	8	15	0	41	18	18	6	6	18

Abbreviations: M₁=minor errors; M₂=major errors; M₁₂=minor and major errors

^aN=107; OKC 76, Tulsa 31

^bN=110; OKC 78, Tulsa 32

^cN=103; OKC 72, Tulsa 31

^dPercentage of students committing minor (M₁), major (M₂), or both minor and major (M₁₂) errors

previous hospital experience, we examined the significance of 3-way interactions involving cohort, time (pre/post) and campus/previous hospital experience (ie, cohort x time x campus/previous hospital experience). There was a significant cohort x time (pre/post) x campus interaction [$b=0.44$ (SE=0.21); $F(1,209)=4.77$, $p=0.03$], indicating that the probability of committing an error pre/post curriculum changes varied by student cohort and campus. The cohort x time (pre/post) x previous hospital experience interaction term was not significant [$b=0.32$ (SE=0.31); $F(1,209)=1.00$, $p=0.32$]. Because of the significant cohort x time (pre/post) x site interaction term, the impact of curriculum changes (pre/post comparisons) were examined and reported with strata defined by cohort and campus location.

At the Oklahoma City campus, cohort 2015 students were significantly less likely to commit errors after the curriculum changes [odds ratio: 0.36; 95% confidence interval (CI): 0.19-0.68] after controlling for a student's previous hospital experience. Cohort 2014 students were also significantly less likely to commit errors after curriculum changes than before the changes (odds ratio: 0.28; 95%CI: 0.15-0.53) after controlling for a student's previous hospital experience. The probability of committing an error (pre/post) did not vary based on a student's previous experience [$\chi^2(3)=0.91$, $p=0.82$]. A student's previous experience was not associated with his/her probability of committing errors across the continuum

of types of errors (minor, major or both; $p>.05$) after controlling for cohort effects (Table 3).

At the Tulsa campus, although there was a decline in the probability of committing errors post curriculum changes, this result was not significant ($p>0.05$). Cohort 2015 students were less likely to commit errors after curriculum changes (odds ratio: 0.36; 95% CI: 0.13-1.01) after controlling for a student's previous hospital experience. Cohort 2014 students were less likely to commit errors after curriculum changes (odds ratio: 0.68; 95% CI: 0.25-1.88) after controlling for a student's previous hospital experience. The probability of committing an error (pre/post) did not vary based on a student's previous experience [$\chi^2(3)=1.17$, $p=0.76$]. A student's previous experience was not associated with his/her probability of committing errors across the continuum of error types (minor, major or both; $p>.05$) after controlling for cohort effects (Table 3).

To determine whether there was a relationship between aseptic compounding errors and cohort membership among third-year students exposed to different components of curriculum, we compared the probability of aseptic compounding errors among third-year student cohorts while controlling for potential influences (moderation or confounding effects) of campus, previous hospital experience and practice site (students nested within practice site; Table 4). Campus and previous hospital experience did not modify (moderate) the association between aseptic compounding errors and cohort membership (interaction term: $p>0.05$).

Table 3. Summary of the Impact of Curriculum Changes on the Probability of Committing an Aseptic Compounding Error after Controlling for Practice Site Cluster Effects

Variable	Oklahoma City Campus Adjusted Odds Ratio (95% CI)			Tulsa Campus Adjusted Odds Ratio (95% CI)		
	M ₁	M ₂	M ₁₂	M ₁	M ₂	M ₁₂
Cohort 2014 ^a						
Second-year	ref	ref	ref	ref	ref	ref
Third-year	0.46 (0.22-0.99) ^c	0.19 (0.07-0.54) ^c	0.15 (0.04-0.57) ^c	0.19 (0.04-1.03)	0.66 (0.19-2.33)	-
Cohort 2015 ^a						
Second-year	ref	ref	ref	ref	ref	ref
Third-year	0.34 (0.15-0.74) ^c	0.29 (0.10-0.82) ^c	0.30 (0.09-0.99) ^c	0.15 (0.04-0.54) ^c	-	0.54 (0.11-2.63)
Hospital experience ^b						
No	ref	ref	ref	ref	ref	ref
Yes	0.90 (0.41-1.98)	1.14 (0.45-2.86)	1.00 (0.31-3.27)	1.03 (0.34-3.14)	0.37 (0.04-3.07)	2.99 (0.71-12.67)

Abbreviations: CI=confidence interval; M₁=minor errors; M₂=major errors; M₁₂=minor and major errors; ref=reference for comparison within cohort

^aAdjusted for previous hospital experience

^bAdjusted for cohort group membership

^cSignificant $p<0.05$

Table 4. Summary of Association between Committing Aseptic Technique Errors at the End of the Third Year and Cohort Group Membership, Hospital Experience, and Campus after Controlling for Practice Site Cluster Effects

Cohort Effect	M ₁ Adjusted Odds Ratio (95% CI)	M ₂ Adjusted Odds Ratio (95% CI)	M ₁₂ Adjusted Odds Ratio (95% CI)
Cohort 2013	ref	ref	ref
Cohort 2014	0.45 (0.23-0.90) ^a	0.22 (0.10-0.48) ^a	0.48 (0.14-1.66)
Cohort 2015	0.43 (0.21-0.87) ^a	0.16 (0.07-0.38) ^a	0.90 (0.30-2.75)
Hospital Experience			
No	ref	ref	ref
Yes	0.64 (0.25-1.67)	0.91 (0.31-2.65)	1.12 (0.30-4.19)
Campus			
Tulsa	ref	ref	ref
Oklahoma City	2.75 (1.39-5.45) ^a	1.96 (0.93-4.15)	1.35 (0.49-3.72)

Abbreviations: M₁=minor errors; M₂=major errors; M₁₂=minor and major errors; CI=confidence interval; ref=reference for comparison

^aStatistically significant $p < 0.05$

Cohorts 2014 and 2015 had a lower probability of committing minor and major errors than cohort 2013 (precurricular change) even after controlling for campus location, previous hospital experience and practice-site clustering effects. Students at the Oklahoma City campus were significantly more likely to commit minor errors than their Tulsa counterparts (odds ratio: 2.75; 95% CI: 1.39-5.45). There was no correlation between aseptic compounding errors and previous hospital experience ($p > 0.05$, odds ratio confidence intervals included 1; Table 4).

DISCUSSION

Implementation of the described curricular changes reduced the likelihood of a student committing aseptic compounding errors on a severity continuum from no error to committing both minor and major errors. This trend applied to both campuses, though only the Oklahoma City campus reached significance, potentially secondary to lower student numbers on the Tulsa campus and less power to confirm significance.

The rates of minor and major errors also were significantly lower in class of 2014 and class of 2015 cohorts than in the class of 2013 cohort, which had not been exposed to the curriculum changes. The second-year sterile product laboratory and third-year institutional IPPE occurred prior to the final third-year technique assessment, so we were unable to determine the individual contribution of either intervention. Third-year spring semester laboratory instructors anecdotally reported much improved sterile product compounding skills during the semester relative to the time before the curricular change and prior to their final assessment.

To better characterize the impact of the third-year summer institutional IPPE on the development/retention

of sterile compounding skills, implementation of an aseptic technique assessment at the beginning of the third-year spring laboratory would be needed. Regardless, because the final third-year assessment at the end of the spring semester represented the time point preceding entry to the APPE year, during which advanced performance is expected, the students demonstrated better quality of sterile product compounding skills after the curricular changes.

Student work experience as an intern in a hospital environment was documented at the start of the second year in order to control for such influence outside the curriculum and was not found to significantly influence the likelihood of error commission. This finding confirmed our suspicion that, while students with existing sterile product preparation experience seemed more “comfortable” with compounding manipulations, improper habits or rapid compounding methods could still predispose students to errors.

We also found that the hospital facility at which a student completed a summer institutional IPPE did not significantly influence that student’s final third-year aseptic technique assessment result. It is desirable for students to have comparable contributions to sterile product preparation during their institutional IPPEs, and while it is difficult to standardize the scope and depth of such experiences, at least we did not find evidence of consistent deficiencies in compounding training by practice site through our analyses.

Findings from studies evaluating personnel and environmental factors contributing to contamination of sterile products have implications for the design and evaluation of aseptic compounding training in pharmacy curricula. Minimizing the potential for touch contamination during sterile compounding is an area of ongoing

improvement for pharmacy students, as contamination of sterile syringes can occur when the lumen comes in contact with environmental surfaces and the hands of the operator.¹² Visual observation of a student's aseptic technique by an experienced pharmacist is essential for corrective feedback, as lapses in aseptic technique show some correlation with the final contamination rate of media-fill tests performed by technicians.¹³

While we did not observe a difference between hospital pharmacy experience as an intern and the likelihood of committing an error during visual assessment, the relationship between experience compounding sterile preparations and the contamination rate of the final product showed conflicting results. Only Isanhart et al showed, when using media-fill testing for pharmacy students in a curriculum, that fewer students who were intravenous-admixture certified technicians produced contaminated syringes at baseline compared to students lacking this certification (0% vs 24%, respectively).⁷ Thomas et al documented that a pharmacy student with 5 years of experience preparing IV admixtures as a technician was significantly ($p=0.012$) more likely to contaminate final products in comparison to a hospital pharmacist with 2 years of experience training others in sterile product preparation.¹⁴

The final contamination rate of sterile product competency evaluations by media-fill testing is lower for pharmacists in comparison to technicians, though pharmacists working regularly in sterile product preparation have slightly higher contamination rates than pharmacists with less experience,¹⁵ and even with direct, regular experience in sterile preparation, pharmacists still can produce contaminated media-fill products.¹⁶ This evidence suggests that proficiency with aseptic compounding cannot be presumed based on position or years of experience. Baseline training, quality assurance procedures to document absence of microbial contamination, and ongoing commitment to personal excellence with sterile product compounding skills can all impact patient safety.

Our assessment method involved visual observation of errors during a syringe transfer of a single additive to a small volume parenteral, which is considered a low-risk compounding procedure. This procedure was selected because it represents one of the most commonly encountered scenarios in hospital pharmacy practice, so students should receive training and corrective feedback accordingly. Though the visually observed error rate should arguably be zero and must be assessed with scrutiny, such errors may not lead to contaminated preparations. In conjunction with visual verification of technique, media-fill testing would better ensure that product sterility is maintained.

Baseline and end-of-course media-fill testing of pharmacy students showed a contamination rate of 5.5 and 0%, respectively, for low-risk sterile compounding procedures⁷ so it seems plausible that significant issues with aseptic technique could be detected for this risk-level. Experienced certified technicians completing more than 1000 syringes for low-risk media-fill testing demonstrated no microbial contamination,¹⁷ which is consistent with the low failure rate seen after instruction of pharmacy students by Isanhart et al.⁷

Visual observation for errors during aseptic compounding procedures requires a high level of vigilance. It is, therefore, possible that some aseptic errors were missed and, as a result, the proportion of "true" errors committed in this study may have been underestimated.

Future studies could consider the use of media-fill testing and visual verification for valid assessment of aseptic compounding errors. Furthermore, comparisons could be made between the proportions of errors detected by these 2 methods to determine the degree or extent of potential misclassification bias attributable using visual verification, assuming media-fill testing is the gold standard.

We intend to continue the current instructional design in terms of the timing of laboratory experiences for second-year and third-year students, though more sterile product repetitions during the second year are desirable in preparation for the summer institutional IPPE. The use of online instructional demonstration videos depicting desirable aseptic compounding techniques greatly contributed to teaching efficiency for the second- and third-year courses, including consistency of instruction. With the majority of video clips depicting focused instruction of less than 4 minutes in length, students can be required to review them outside of class in preparation for their hands-on laboratory sessions and also re-review them as needed.

In comparison to a laboratory model where students have a high number of sterile product laboratories during a semester but complete a small number of preparations per laboratory, we favor fewer laboratories with a high number of sterile product preparations per laboratory to foster skill development. This also allows for more efficient instructional time during the formative laboratory sessions, where repeated aseptic technique manipulations can be reviewed in 30 to 45 minutes using a low instructor-to-student ratio. Specific feedback can then be provided to students, and subsequent observations can verify progress. A summative evaluation of medium-risk compounding techniques could be added to our assessment process, as we are only providing summative assessment for low-risk compounding. We also continue to discuss whether to

implement media-fill testing to evaluate microbial contamination of a prepared product in concert with our visual assessment methods.

Our discussions with local hospital facilities regarding media-fill testing for our students prior to IPPE or APPE rotations are ongoing. When students are enrolled in experiential coursework, our state pharmacy law allows them to assist qualified pharmacists in preparing sterile products under their direct supervision provided that specific training requirements are met.¹⁸

A remaining question for investigation is the retention and demonstration of proper aseptic compounding skills during the APPE year. For some students, the institutional APPE may be scheduled up to 11 months after their last formal instruction in our third-year curriculum. Preceptor observation and verification of sterile product compounding techniques in actual practice environments according to facility procedures will remain essential, but curricular depth and frequency of preparatory instruction/assessment are areas for continued research.

It is important to acknowledge limitations of this study. While the pre/posttest design used in this evaluation allowed us to examine the potential effects of curriculum changes on the probability of committing errors among students, this design cannot be used to determine if pre/post changes in the probability of committing errors would have occurred in the absence of curriculum changes. It is possible that improvements in aseptic compounding (reduced errors) could be a result of students becoming accustomed to the procedures (eg, observation by faculty members and checklists) used for error assessments rather than changes in the curriculum.

To obtain unbiased effects of curriculum changes, a randomized study design would be needed to control for unknown or unmeasured potential confounding factors that may mask or bias intervention effects. The potential also exists for variation in instructor observation and assessment within and between campuses. Because of lower student numbers, the Tulsa student campus had more consistent faculty instruction, and one faculty member conducted the majority of all second-year and third-year assessments for all cohorts. At the Oklahoma City campus, several faculty members were required to conduct the second-year instruction and assessments, although one instructor conducted the third-year assessments for all cohorts. Whether the consistency of instruction and formative feedback in Tulsa accounts for the difference observed between campuses is unknown. We attempted to control instructor variance through orientation and postassessment debriefing, and one instructor in Oklahoma City reviewed all of the assessment data for second-year and third-year assessments.

SUMMARY

After implementing an aseptic technique compounding laboratory during the spring semester of the second year and an 80-hour institutional IPPE during the summer prior to the third year, instructor visual assessment of aseptic technique for low-risk product preparation showed a reduction in minor and major errors during the third-year spring semester, significantly among students on the Oklahoma City campus. In comparison to the third-year student class receiving only one semester of aseptic compounding laboratory experiences (precurriculum change), 2 consecutive third-year student classes showed significantly lower probability of committing minor and major aseptic technique errors by instructor visual assessment. Student self-report of hospital intern experience prior to the second-year laboratory and practice site of summer institutional IPPE assignment did not influence the probability of committing aseptic technique errors.

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Appendix 1. Aseptic Technique Checklist for a Single Additive Parenteral

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1.	Assembles supplies before compounding.
2.	Removes jewelry.
3.	Lathers for 15-30 seconds.
4.	Washes up to elbows; rinses toward elbows.
5.	Uses paper towel to shut off faucet.
6.	Correctly applies gloves.
7.	Cleans/disinfects laminar hood using correct technique.
8.	Works at least 6 inches (or 1/3 of depth) inside the hood. ^a
9.	Correctly stages vials/materials in the hood.
10.	Does not obstruct sterile air with hands or supplies. ^a
11.	Removes vial flip tops inside the hood.
12.	Removes IV bag overwrap appropriately (if applicable).
13.	Correctly stages IV bag(s) in the hood.
14.	Sprays or swabs vial top(s) and IV bag port(s) with alcohol. ^a
15.	Selects proper size syringe for additive volume.
16.	Correctly inserts needle into vial.
17.	Uses proper techniques for compounding: Correct rotation of vial off desktop (no finger or object passes in front of sterile site^a) Maintains slight negative pressure within vial(s) (correct rotation of vial back to the desktop) No finger or object passes in front of sterile site^a (correct insertion of needle into IV bag port) No finger or object passes in front of sterile site^a (does not contaminate plunger barrel with fingers) Final additive volume is correct
18.	Does not contaminate any sterile site. ^a
19.	Uses proper technique to recap syringe needle if needed.
20.	Checks products for expiration date and particulate matter.
21.	Applies seal to IV bag (if required).
22.	Accurately labels final product.
23.	Avoids touching face, hair, or contaminated surfaces without subsequent disinfection. ^a
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Abbreviations: IV=intravenous

^aSources of major errors