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QUALITY IMPROVEMENT

A Comprehensive Bone Marrow Aspirate and Biopsy Educational Program Utilizing Task Trainers

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Abstract

Background: Advanced practice providers (APPs) who care for patients with hematologic malignancies perform bone marrow aspiration and biopsies (BMBXs). Invasive bedside procedures are often taught through the observational training method, which can lead to inconsistencies. **Problem:** The purpose of this project was to create and evaluate a standardized educational curriculum incorporating simulation with a task trainer for bone marrow transplant (BMT) APPs. The project aimed to reduce BMBX incident reporting events, improve BMBX knowledge, and increase APP self-reported confidence. **Methods:** Pre- and post-test surveys were utilized for knowledge assessment of BMBX procedures and specimen allocation. Program delivery occurred on five occasions to accommodate the needs of the team. Each program was delivered over 3 hours and included an educational Microsoft PowerPoint and three breakout sessions: BMBX kit review; simulation on task trainer; and review of BMBX specimen collection procedures. Knowledge assessment surveys were compared through descriptive and statistical analysis. **Results:** BMBX incident reporting events decreased from 1.92 events per month pre-implementation to 1.2 events per month post-implementation. Overall, BMBX knowledge increased from 41.02% on pre-test surveys to 65.72% on post-test surveys. Participant self-reported confidence improved by a mean difference of –1.85 based on a 5-point Likert scale, $t(12) = -1.85$ ($p \leq .0001$, 95% confidence interval = –2.49 to –1.2). **Implications:** This project suggests that the use of simulation with task trainers is beneficial when paired with a standardized educational curriculum. Simulation training for APPs who perform BMBX improves procedural knowledge, increases self-reported confidence, and can reduce incident reporting events.

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Hematologic malignancies encompass acute or chronic leukemias; lymphomas; and plasma cell disorders. In 2023, it was estimated that approximately 184,720 people in the United States were diagnosed with leukemia, lymphoma, or myeloma (Leukemia & Lymphoma Society, 2023). The diagnosis of hematologic malignancies is often dependent upon the successful performance and collection of specimens from a bone marrow aspiration and biopsy (BMBX). Given the invasive nature of the procedure, it is essential that the proceduralist perform the BMBX correctly to yield quality specimens sufficient for diagnostic testing. The appropriate handling and deposition of specimens collected ensure the viability of samples received by the hematopathologist for processing. Bone marrow testing has become increasingly sophisticated, and incorrect placement of a core biopsy into the wrong medium or insufficient aspirate volume will potentially delay diagnosis. The successful completion of BMBX and accurate handling of specimens may prevent the need for a repeat procedure.

PURPOSE AND OBJECTIVES

Bone marrow transplant (BMT) advanced practice providers (APPs) at a large academic medical center recognized variation in BMBX technique among their group. This BMT APP group performs 98% of all BMBXs at the institution, while the hematology fellows perform the other 2%. Historically, BMT APPs at this institution learned how to perform BMBXs through the observational teaching method on patients regardless of experience. Previously, no formal educational program or simulation training was utilized to teach APPs how to successfully perform the procedure.

The implementation of simulation training with Bonnie Bone Marrow Biopsy Skills Trainer to aid in the standardization of procedure technique was used to avoid undue risk and complications with live subjects. A review of the incident reporting system (IRS) was completed to search for any potential bleeding or infectious complications reported following BMBXs and yielded none. However, the IRS incidentally revealed errors in specimen labeling, handling, and processing reported by the laboratory staff. The IRS highlighted that educating APPs regarding specimen collection and allocation was important because it was incorrectly assumed APPs knew how to complete these steps properly.

AVAILABLE KNOWLEDGE

A systematic review of the literature found that simulation training provides an opportunity for learners to process complex, multistep procedures and practice procedural skills on mannequins or task trainers in low-pressure environments (Nestel et al., 2011; Von Cranach et al., 2019). Participants in simulation training express high levels of satisfaction, knowledge gain, and improvement in skills (Gaubert et al., 2021; McMillan et al., 2016; Nestel et al., 2011; Von Cranach et al., 2019). Most institutions still train new providers through observational models or the "see one, do one" teaching approach, which leads to variability in skills and levels of confidence (McMillan et al., 2016). Interactive standardized teaching with simulators may reduce provider variability; reduce the development of unintentional procedural errors; enhance confidence levels; and show statistically significant improvements in competency, skill retention, and complication rates (Gaubert et al., 2021; Lenchus et al., 2011; McMillan et al., 2016; Reiss et al., 2017). Two large quality improvement projects that assessed the relationship between proceduralist and BMBX specimen quality concluded that formal BMBX education for proceduralists can be one of the single biggest factors for overall specimen yield and quality (Marinelli et al., 2018; Yang et al., 2018).

The literature lacks evidence surrounding the use of simulation training on task trainers for BMBXs to enhance the proficiency of procedural skill acquisition specifically for APPs but shows it has been utilized and accepted within physician medical education (Reiss et al., 2017; Yap et al., 2015). As compared to physician medical education, the use of a task trainer is cheaper than the costs associated with training with cadavers (VanderMeulen et al., 2021). The use of a task trainer is associated with the initial upfront cost to purchase the simulator and subsequent replacement parts, which provides a more sustainable model for ongoing training.

The primary evaluation question was to determine whether the implementation of a comprehensive BMBX educational program including task trainers could achieve a 10% reduction in BMBX incident reports between July 2021 and March 2022. Additional outcome measures aimed to increase BMT APP knowledge of BMBX procedures including specimen allocation by 25% from baseline and to increase self-reported procedure confidence by training with the task trainer by an average of 1 point on a 5-point Likert scale.

METHODS

Sample

This program evaluation (PE) project took place at a large level 1 trauma center and academic medical center in the United States. All existing BMT APP staff, those hired prior to May 2021, and new staff hired between May 2021 and December 2021 met inclusion criteria. Advanced practice providers hired after December 2021 were excluded, as a complete data set would exceed the end of the data collection period for the purposes of this project. Participants included six nurse practitioners and seven physician assistants. Five participants were in their first year of APP practice, three had 1 to 3 years of experience, two had 3 to 5 years of experience, and three participants had more than 5 years of experience. Eight participants were new hires while the remaining five were existing staff. Of the eight new hires, two had prior experience performing BMBXs while the remaining six were new to the procedure.

Procedures

As part of baseline data collection, a pre-implementation survey was sent electronically to BMT APP staff in spring 2021. The survey included a variety of questions that captured demographics, baseline specimen collection knowledge, and BMBX procedure knowledge. At the time of baseline data collection, 18 of 24 (75%) BMT APPs completed the survey. Analysis of the questions and responses revealed knowledge gaps on nine specific topics, including morphology, BMBX aspirate clot, cytogenetics/fluorescence in situ hybridization, molecular next-generation sequencing (NGS), and BMBX cores; appropriate wait time following subcutaneous lidocaine administration; appropriate ChloraPrep cleanse and dry time; location of tissue bank consent; and the correct number of BMBX cores required when a marrow is deemed inaspirable. These topics were identified and selected as the focus for the educational curriculum, as BMT APPs answered these questions correctly less than 66% of the time. The baseline data collection surveys further validated that staff would benefit from a standardized educational curriculum.

The project was created by the primary author then reviewed with BMT stakeholders. The curriculum was all-inclusive and detailed indications for procedure; risks and complications; informed consent; time-out protocol; review of the pelvic anatomy including bony structures, musculature, and surrounding vasculature; extensive review of the BMBX kit; exhaustive step-by-step process of procedure; aftercare for patient; and the correct specimen allocation of material for laboratory testing.

The use of the Bonnie Bone Marrow Biopsy Skills Trainer was utilized for this project. This simulation device is a task trainer specifically for clinicians learning BMBX via the posterior iliac approach. This task trainer includes an adult-sized pelvis covered with a skin surface that can be punctured for realism and can be used in prone or side-lying positions. While the task trainer does not provide liquid aspirate, it does allow learners to collect a core biopsy. With the use of this task trainer, learners are able to simulate patient positioning, palpating the correct anatomical site for the procedure, and performing each step of the procedure for correct specimen collection.

To accommodate the needs of the team and the timing of new hire APP onboarding, delivery of the program occurred on five separate occasions during the data collection period. One week prior to program delivery, pre-test surveys were sent electronically to participants. The curriculum was delivered as a 60- to 90-minute Microsoft PowerPoint including videos created by the author and co-facilitators. Participants then engaged in three hands-on breakout sessions: specimen sequence with allocation, BMBX kit review, and simulation of the procedure on the task trainer. Program sessions were capped at four participants. If participants had prior BMBX experience, they would start with either the specimen sequence with allocation or simulation on the task trainer as their first breakout session. If participants were new to BMBX, they would start with the BMBX kit review. Most participants remained at each breakout session for 30 minutes prior to rotating to the next. One week following program delivery, post-test surveys were sent electronically. Weekly reminder emails were sent until survey completion.

Measures

Incident reporting events specific to BMBXs were reviewed starting in January 2020. Events dating back prior to the pandemic were felt to be important as it was hypothesized that events increased in 2020 as the result of reduced laboratory staff due to SARS-CoV-2 staffing shortages. Historically, inpatient laboratory staff would handle BMBX intraprocedural specimens at the bedside, which allowed for the APP to focus solely on the patient and completion of the procedure.

Additional outcome measures aimed to increase BMBX knowledge by 25% over baseline following program implementation while also striving to increase BMT APP self-reported confidence by an average of 1 point on a 5-point Likert scale. Post-test surveys included an open text box where participants could provide additional feedback. These outcome measures were created specifically to assess APP knowledge gain and confidence levels with standardized training. Given that the surveys were specific for this program, there is no established reliability or validity to report.

Funding

The Division of Hematology (DOH) supported the development of this project from its inception. New hires participated in the program during their orientation period, which is considered non-billable time. Therefore, there was no additional financial impact. Co-facilitators and existing staff participated in the program on a voluntary basis.

The DOH contributed to the success of this project by purchasing the task trainer, Bonnie Bone Marrow Biopsy, that was used during each program. With the initial purchase of the task trainer, replacement right and left posterior iliac crests were ordered. These replacement parts are essential for the ongoing use of the task trainer and anticipated to last for an average of 20 programs with an estimated 200 accesses.

Ethical Considerations

This PE project was approved by a University of Colorado College of Nursing proposal review committee on behalf of the Colorado Multiple Institutional Review Board in June 2021. Confidentiality of participants' survey responses were the primary ethical concern. Results of surveys were analyzed, reported, and data stored in a password-protected Microsoft Excel file on a password-protected laptop.

ANALYSIS OF DATA

BMBX Incident Reporting Events

The primary outcome measure was to reduce BMBX incident reporting events by 10%. This outcome was met as events decreased by 62.5% following program implementation with a decrease from a baseline average of 1.92 events per month to 1.2. The highest number of events entered during the project cycle occurred in December 2021 and January 2022 while no events were entered from August 2021 through November 2021. A run chart (Figure 1) displays the number of events per month from January 2020 through March 2022. The PE implementation period spanned from July 2021 through March 2022. Due to the descriptive nature of the data set, statistical tests of significance were not measured for this outcome.

BMBX Knowledge

The second outcome measure was to improve BMT APP BMBX knowledge by 25% over baseline. This was met as overall BMBX knowledge improved from a baseline of 41.02% to 67.52% on post-test surveys. Post-test surveys showed the largest knowledge gains included the location of tissue bank consent in the chart, correct lidocaine administration procedure, and the accurate tube or container allocation for BMBX clot, core, and aspirate for NGS testing. Participants surveys were individually analyzed to compare their baseline to their knowledge gained. Some participants demonstrated a loss of knowledge (2 of 13) while most increased their knowledge with a range of –22.22% to 66.67%. Knowledge question and participant data including variance are detailed in Tables 1 and 2.

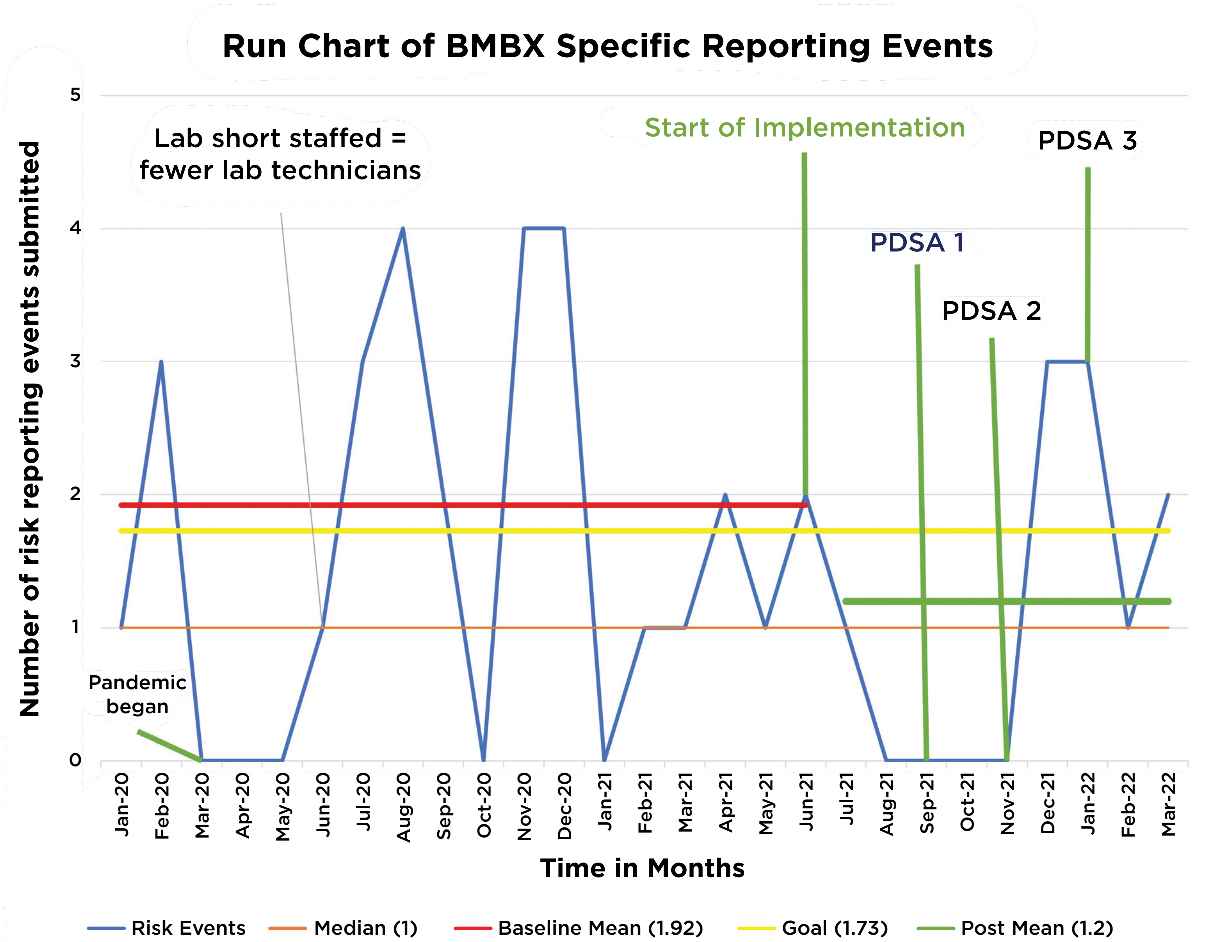

Figure 1. Run chart of bone marrow aspiration and biopsy–specific reporting events. PDSA = Plan-Do-Study-Act.

Self-Reported Confidence

The third outcome measure aimed to improve BMT APP self-reported confidence by an average of 1 point on a 5-point Likert scale. The Likert scale ranged from completely confident (1) to not at all confident (5). This outcome was met as self-reported confidence improved from a pretest mean of 3.38 (95% confidence interval [CI] = 2.71 to 4.06) to a post-test mean of 1.54 (95% CI = 1.22 to 1.85). The mean difference was –1.85 (95% CI = –2.49 to –1.2) with a statistically significant $p \leq .0001$. Self-reported confidence was analyzed by paired *t*-test. Of note, the Likert scale on pre- and post-test surveys was inadvertently listed as an inverse which resulted in a mean difference of –1.85, however, this represented an improvement. This data is displayed as histograms in Figure 2.

Qualitative Data

Post-test surveys included qualitative data questions that further supported the impact and emphasized the importance of ongoing utilization. All participants found the Microsoft PowerPoint curriculum and simulation training with the task trainer to be helpful in their understanding of the procedure. All participants found the breakout sessions for review of specimen collection and container allocation to be valuable. All believed participation in the program with use of the task trainer prior to first patient experience would enhance patient safety. Of the eight new hires, all participants felt the program benefited them during their orientation, while all 13 participants would recommend the program be embedded as part of the new hire orientation period.

Table 1. Bone Marrow Aspiration and Biopsy Knowledge Results and Variance

Knowledge questions	Pre-program % correct	Post-program % correct	Variance, %
BMBX morphology	46.15	38.46	–7.69
Lidocaine administration	7.69	46.15	38.46
BMBX clot	53.85	84.61	30.76
ChloraPrep application	61.54	76.92	15.38
BMBX cytogenetic/FISH	53.85	76.92	23.07
BMBX core	23.08	69.23	46.15
BMBX NGS panel	30.77	76.92	46.15
BMBX inaspirable cores	23.08	38.46	15.38
Tissue bank consent	69.23	100.00	30.77

Note. BMBX = bone marrow aspiration and biopsy; FISH = fluorescence in situ hybridization; NGS = next-generation sequencing.

Post-test surveys included an open discussion box for feedback. Participant A described the program as "very organized, and the material was easy to understand." Participant B appreciated "the review of what goes in what tube." Participant D commented that the program provided "a great review of techniques," and Participant I mentioned it would be helpful to have "the opportunity to do procedures as soon as possible following the program." Participant M stated the program "was extremely helpful" and thought the program was "a great addition to the orientation process." The feedback of participants, in addition to the quantitative data analysis, supports the ongoing use of this project for future BMT APPs.

DISCUSSION

Although a reduction in the BMBX IRS was seen with the implementation of this PE project, it is unknown if these results are directly due to implementation. The entry of incident events into the system is dependent upon individuals taking the time to input the information. This project took place during surges of the SARS-CoV-2 pandemic, which may have impacted the entry of events. The improvement in baseline knowledge was encouraging and suggests that further reinforcement

Table 2. Participant Knowledge Gain and Variance

Knowledge questions	Pre-program % correct	Post-program % correct	Variance, %
Participant 1	33.33	55.56	22.23
Participant 2	55.56	66.67	11.11
Participant 3	22.22	77.78	55.56
Participant 4	66.69	44.44	–22.23
Participant 5	22.22	88.89	66.67
Participant 6	22.22	88.89	66.67
Participant 7	44.44	66.67	22.23
Participant 8	22.22	88.89	66.67
Participant 9	88.89	66.67	–22.22
Participant 10	33.33	66.67	33.34
Participant 11	77.78	100.00	22.22
Participant 12	33.33	44.44	11.11
Participant 13	11.11	22.22	11.11

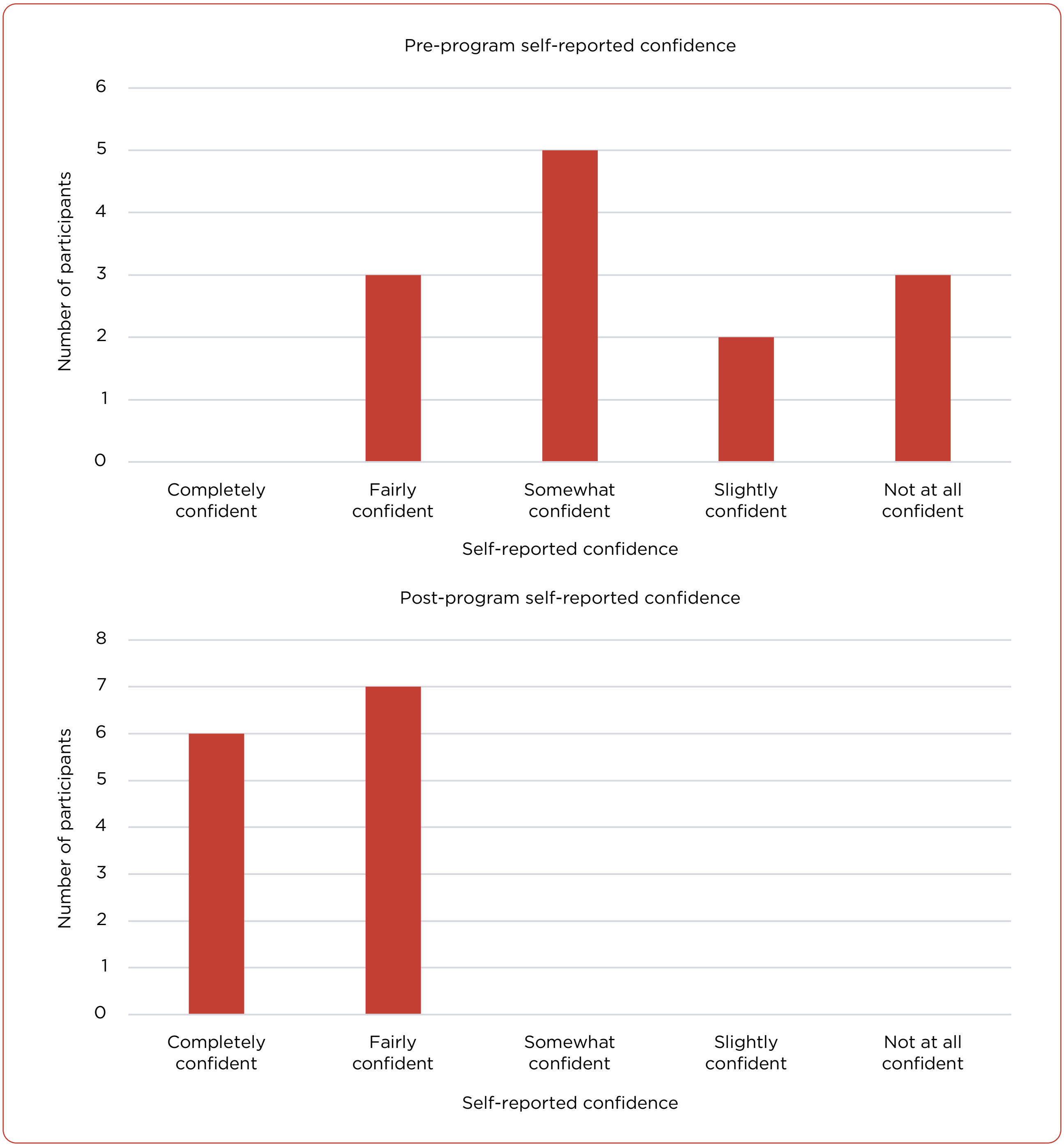

Figure 2. Pre- and post-program participant self-reported confidence.

of information can be beneficial for new hires as they continue to perform BMBXs. The improvement in self-reported confidence by Likert scale parallels the body of knowledge that was found in the physician-based simulation training literature (Brondfield et al., 2021; McMillan et al., 2016; Von Cranach et al., 2019).

Interpretation

Advanced practice providers are capable and competent to develop protocols and educational programs to train colleagues to successfully perform BMBXs (Jackson et al., 2012). The development and implementation of a BMBX educational program utilizing task trainers for this BMT APP group was beneficial. The program was most fruitful for APPs new to the procedure. All participants reported that they felt the program was important for BMT APP education and could lead to improved patient safety. While this was a single institution Doctor of Nursing Practice student-lead project, it adds to the nonexistent literature regarding the use of simulation with task trainers by APPs performing BMBXs.

The impact of this project was overwhelmingly positive. The program is now embedded in the new hire orientation process and will continue to be an added benefit to the overall experiential process of this institution's BMT APP team. The standardized curriculum is evidence-based and the utilization of the BMBX task trainer allows learners to gain the mechanical, cognitive, and interactive skills necessary for this multistep procedure (Yap et al., 2015). While this project was nonrevenue generating, it does have a clinically significant impact on the system as procedures such as BMBX are reimbursable from the various payor mix.

Limitations

Limitations of the project include a small sample size, lack of participation from existing staff, single-site institution, lack of generalizability, and use of a needs-specific unvalidated tool created specifically for this APP group. There were no limitations related to the participation of new hires who onboarded in 2021. The participation of existing staff was multifactorial and impacted primarily by staffing shortages during various phases of implementation. There was no perceived bias. The use of an unvalidated instrument specific for this institution and APP group can be considered an imprecision of design.

CONCLUSIONS AND IMPLICATIONS FOR APPs

This project demonstrated that the implementation of an educational curriculum with simulation on task trainers for APPs who perform BMBXs is beneficial in improving self-reported confidence and knowledge. Although cause and effect cannot be determined with PE projects, the reduction in BMBX incident reporting events was clinically significant and suggests that further work in this area is warranted.

While the planned inclusion of this program in the new hire orientation process will promote its longevity, it can be further utilized for the maintenance of clinical competency. Next steps include the addition of existing staff as co-facilitators to familiarize themselves with the standardized curriculum and to encourage involvement in upcoming program delivery. Future work could include asking prior participants to retake the post-test survey to assess for knowledge retention.

This work can be adapted and reproduced at other institutions or practices where APPs perform BMBXs. If other sites seek to measure knowledge gain, it will be essential for project coordinators to obtain their own unique baseline data to guide educational curricular foci. The successful acquisition of BMBX skills may lead to fewer procedural-related complications and reduced resource utilization, therefore alleviating future costs to the health-care system.

There is currently no existing literature that describes the use of task trainers for the training of APPs for the performance of BMBX. This novel work supports and encourages the use of simulation training with the use of task trainers or other mannequins in APP models of care for the purposes of procedural skill achievement and improved self-reported confidence. When paired with evidence-based instructional design, opportunities exist to promote APP competency and elevate patient care. ●

Disclosure

The authors have no conflicts of interest to disclose.

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