The Impact of a Medical Procedure Service on Patient Safety, Procedure Quality and Resident Training Opportunities

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BACKGROUND: At some academic hospitals, medical procedure services are being developed to provide supervision for residents performing bedside procedures in hopes of improving patient safety and resident education. There is limited knowledge of the impact of such services on procedural complication rates and resident procedural training opportunities.

OBJECTIVE: To determine the impact of a medical procedure service (MPS) on patient safety and resident procedural training opportunities.

DESIGN: Retrospective cohort analysis comparing characteristics and outcomes of procedures performed by the MPS versus the primary medical service.

PARTICIPANTS: Consecutive adults admitted to internal medicine services at a large academic hospital who underwent a bedside medical procedure (central venous catheterization, thoracentesis, paracentesis, lumbar puncture) between 1 July 2010 and 31 December 2011.

MAIN MEASURES: The primary outcome was a composite rate of major complications. Secondary outcomes included resident participation in bedside procedures and use of “best practice” safety process measures.

KEY RESULTS: We evaluated 1,707 bedside procedures (548 by the MPS, 1,159 by the primary services). There were no differences in the composite rate of major complications (1.6 % vs. 1.9 %, $p=0.71$) or resident participation in bedside procedures (57.0 % vs. 54.3 %, $p=0.31$) between the MPS and the primary services. Procedures performed by the MPS were more likely to be successfully completed (95.8 % vs. 92.8 %, $p=0.02$) and to use best practice safety process measures, including use of ultrasound guidance when appropriate (96.8 % vs. 90.0 %, $p=0.0004$), avoidance of femoral venous catheterization (89.5 vs. 82.7 %, $p=0.02$) and involvement of attending physicians (99.3 % vs. 57.0 %, $p<0.0001$).

CONCLUSIONS: Although use of a MPS did not significantly affect the rate of major complications or resident opportunities for training in bedside procedures, it was associated with increased use of best practice safety process measures.

KEY WORDS: bedside procedures; medical education; medical procedure services.

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INTRODUCTION

Internal medicine physicians commonly perform invasive bedside procedures for diagnostic and therapeutic purposes. Historically in teaching hospitals, junior residents supervised by senior trainees performed most of these procedures. Belying the effectiveness of this ‘see one, do one, teach one’ model, many senior internal medicine residents report lack of confidence in their ability to perform such procedures independently, and frequently report supervising less experienced trainees before having achieved comfort with the procedure themselves.^{1,2}

Invasive bedside procedures expose patients to harm. In the Medical Practice Study, procedural complications were the second most common cause of adverse events among hospitalized patients.^{3,4} Although serious complications are rare, they can be life threatening, raising questions about whether these procedures should be performed by housestaff alone.

In the past decade, several interventions have been proposed to improve safety of bedside procedures. One intervention is the formation of medical procedure services (MPS), which provide formal procedural supervision by skilled attendings for trainees performing bedside procedures.^{5–8} While medical procedure services improve resident comfort performing bedside procedures,^{5,9,10} it remains unknown whether such services decrease risk of complications or improve procedural training opportunities.

METHODS

Design Overview

Our goal was to compare characteristics and outcomes of procedures performed by the MPS versus the primary medical services at a large teaching hospital. The MPS at Boston Medical Center was introduced in 2007 to supervise

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or independently perform bedside medical procedures weekdays from 9 AM to 5 PM. It is staffed by five pulmonary and critical care physicians (one dedicated attending per weekday). Two junior or senior residents at a time may elect to rotate with the MPS for up to 2 weeks per year. Clinicians who choose to consult the MPS have the option of requesting supervision to perform the procedure, or deferring performance to the MPS. Procedures performed include central venous catheter (CVC) placement, lumbar puncture, paracentesis, thoracentesis, chest tube placement and peripherally inserted central catheter (PICC) placement. During our study period, the MPS performed an average of 9.6 procedures per week (including all procedures performed on any service).

We performed a retrospective chart review of all adults (age ≥ 18) who underwent a bedside medical procedure between 1 July 2010 and 31 December 2011 while admitted to an internal medicine service. All chart reviews were performed by a single investigator (MHT). For this study, we defined “bedside medical procedures” to include those that were historically expected to be mastered during internal medicine residency: thoracentesis, paracentesis, lumbar puncture, and CVC placement; we excluded chest tube and PICC placement. Although the MPS is available to all services for consultation, given inherent differences in patient populations admitted to medicine and non-medicine services, procedures performed by the MPS on non-medicine services were excluded. At Boston Medical Center, since 2010, all procedures performed by internal medicine clinicians are expected to be documented using a standardized procedure note template; we identified bedside medical procedures by accessing all notes in the electronic medical record that used this template.

Patient demographics, procedural characteristics and outcomes were determined through review of the electronic medical record. The procedure note template includes fields for procedure type, ultrasound use, names and level (resident, fellow, attending) of participants, and whether the procedure was successfully completed. This study was approved by the Boston University Medical Campus Institutional Review Board (H-31437).

Impact of the MPS on Patient Safety

Our primary outcome was a composite rate of major complications. For CVC placement, a major complication was defined as arterial cannulation, pneumothorax, hemothorax, or central line associated blood stream infection (CLABSI). For thoracentesis, a major complication was defined as pneumothorax, hemothorax or organ puncture. For lumbar puncture and paracentesis, major complications were defined as organ damage or hemorrhage requiring blood transfusion.

To identify cases of iatrogenic pneumothorax, hemothorax, and catheter malpositioning, we reviewed reports of all

chest radiographs performed within 24 h of internal jugular or subclavian CVC placement and thoracentesis. To identify cases of CLABSI, we used data previously collected by the hospital’s infection control nurses (prospective chart review on all patients with positive blood cultures to determine whether they met the Center for Disease Control & Prevention criteria for CLABSI).¹¹ To identify other major complications, we reviewed all attending physician progress notes and reports of other relevant imaging performed within 72 h of the procedure.

We performed additional analyses exploring our primary outcome. First, we performed a subgroup analysis in which we report complication rates of the MPS versus the primary services stratified by whether the patient was admitted to the intensive care unit (ICU). We performed a sensitivity analysis including CVC malpositioning requiring catheter replacement or removal as a major complication.¹² Finally, given that the MPS is unavailable on nights and weekends, we performed a sensitivity analysis restricting our comparison of complication rates to procedures performed on weekdays.

Additional secondary outcomes related to patient safety included the proportion of procedures that were successfully completed and the use of “best practice” safety process measures. An unsuccessful procedure was defined as a procedure that was unable to be completed by the original operator irrespective of number of procedure attempts. Best practice safety process measures were defined as those processes recommended by guidelines and implemented to increase safety: use of ultrasound guidance during internal jugular or femoral CVC and thoracentesis; selection of preferred CVC site (subclavian or internal jugular vein as opposed to femoral vein); and attending-level participation (either as supervisor or primary operator).^{11,13,14}

Impact of the MPS on Resident Training Opportunities

As a secondary outcome, we examined the proportion of procedures performed by the MPS as compared to the primary medical services with documented resident participation. We reviewed procedure notes to identify all documented participants. We defined residents as post-graduate year (PGY) 1–3 and fellows as PGY4–7. For this portion of the analysis, we excluded procedures performed on non-teaching services (services without resident involvement).

Statistical Analyses

We calculated descriptive statistics for continuous variables with means and standard deviations. Associations between procedure characteristics and the service performing the procedure were analyzed using *t*-tests for continuous

variables and chi-square analysis or Fisher's exact test for categorical variables. For all statistics, a two-sided p value of < 0.05 was considered statistically significant. Statistical tests were performed using SAS version 9.1.3 (Cary, NC).

RESULTS

Procedure Characteristics

Over the 18-month study period, the MPS was consulted to perform 32.1 % (548/1707) of bedside procedures on patients admitted to medical services. The MPS performed 52.1 % of procedures performed on weekdays. Characteristics of the procedures are shown in Table 1. The MPS performed the majority of thoracenteses (67.4 %), while the primary services performed most CVC placements (79.0 %), paracenteses (56.2 %) and lumbar punctures (68.7 %). While the primary services performed most (75.8 %) of their procedures in the ICU, less than half (46.9 %) of MPS procedures occurred in the ICU ($p < 0.0001$).

Impact of MPS on Patient Safety

Overall, major complications were uncommon, occurring in 1.8 % (95 % CI 1.2–2.5 %) of bedside medical procedures. Most complications (74.2 %, 95 % CI 59.8–89.6 %) were associated with CVC placement. The most common complications associated with CVC placement were pneumothorax (47.8 %, 95 % CI 27.4–68.2 %) and CLABSI (39.1 %, 95 % CI 19.2–59.1 %). Pneumothorax accounted for 71.4 % (95 % CI 37.9–100 %) of complications associated with thoracentesis. While other procedure-related complications were rare ($n=3$), they tended to be life-threatening. One episode of bowel perforation and one

episode of hemothorax complicated thoracenteses; both required major surgery. One episode of hemorrhage associated with paracentesis required operative intervention. No deaths directly attributable to bedside medical procedures were observed.

The rate of major complications was similar between the MPS and primary services, both overall (1.6 % vs 1.9 %, $p=0.71$) and when stratified by ICU status (Table 2). When we restricted our analysis to the procedure with the highest rate of complications, CVC placement, there was no statistically significant difference in the rate of major complications among procedures performed by the MPS versus the primary services (1.0 % vs 2.7 %, $p=0.20$). This finding was unaffected by our sensitivity analysis including catheter malpositioning as a major complication (3.3 % vs 5.5 %, $p=0.21$). Similarly, the complication rates were unchanged when the analysis was limited to procedures performed on weekdays: 1.7 % vs 1.2 %, $p=0.54$.

The MPS performed significantly better than the primary services on the secondary safety-related outcomes (Table 2). The MPS had a significantly lower rate of unsuccessful procedures (4.2 % vs 7.2 %, $p=0.02$). The MPS reported higher use of appropriate ultrasound guidance (96.8 % vs. 90.0 %, $p=0.0004$) and lower rates of femoral CVC (10.5 % vs. 17.3 %, $p=0.02$). Finally, procedures performed by the MPS were significantly more likely to document attending participation (99.3 % vs. 57.0 %, $p < 0.0001$).

Impact of MPS on Resident Training Opportunities

Residents participated in just over half of bedside medical procedures (55.3 %, 95 % CI 52.8–57.8 %). The proportion of resident involvement did not differ based on whether the MPS or primary service performed the procedure (57.0 % vs. 54.3 %, $p=0.31$), nor on whether the procedure was performed during weekday or 'off-hours' (weekday MPS, 57.8 %; weekday primary service: 52.9 %; nights or weekend primary service: 54.8 %; $p=0.30$). While the MPS was more likely to involve residents in CVC placement (48.3 % vs. 39.6 %, $p=0.03$), residents were more likely to be involved in other procedures when performed by the primary service: thoracenteses (71.6 % vs. 53.7 %, $p=0.01$), paracenteses (86.2 % vs. 70.1 %, $p=0.001$), lumbar punctures (83.5 % vs. 67.7 %, $p=0.02$).

Overall, 89.2 % (95 % CI 87.7–90.8 %) of procedures performed on internal medicine teaching services documented participation by either an attending or fellow. Attending physicians participated in virtually all (99.7 %, 95 % CI 99.1–100 %) procedures performed by the MPS with documented resident participation. By contrast, on the primary services, only 47.0 % (95 % CI 42.7–51.2 %) of procedures with resident participation documented attend-

Table 1. Characteristics of Bedside Procedures

	Medical Procedure Service	Primary Services	p value
Total Procedures (%)	548/1,707 (32.1)	1,159/1707 (67.9)	
Procedure			< 0.0001
Central Line	210/548 (38.3)	788/1,159 (68.0)	
Thoracentesis	149/548 (27.2)	72/1,159 (6.2)	
Paracentesis	127/548 (23.2)	163/1,159 (14.1)	
Lumbar Puncture	62/548 (11.3)	136/1,159 (11.7)	
Patient Characteristics			
Age (mean [SD])	57.3 (15.1)	57.5 (15.7)	0.46
Female Sex	233/548 (42.5)	440/1,159 (38.0)	0.07
Critically ill (ICU patient)	257/548 (46.9)	878/1,159 (75.8)	< 0.0001

Table 2. Impact of the Medical Procedure Service on Patient Safety

	Medical Procedure Service (n=548)	Primary Services (n=1159)	p value
Complications (%)			
All	9/548 (1.6)	22/1,159 (1.9)	0.71
ICU patients	3/257 (1.2)	19/878 (2.2)	0.44
Non-ICU patients	6/291 (2.1)	3/281 (1.1)	0.50
Central Line	2/210 (1.0)	21/788 (2.7)	0.20
Pneumothorax	1/210 (0.5)	10/788 (1.3)	0.47
CLABSI	1/210 (0.5)	8/788 (1.0)	0.69
Arterial Placement	0/210 (0)	3/788 (0.4)	1.0
Thoracentesis	6/149 (4.0)	1/72 (1.4)	0.43
Pneumothorax	4/149 (2.7)	1/72 (1.4)	1.0
Paracentesis	1/127 (0.8)	0/163 (0)	0.44
Lumbar Puncture	0/62 (0)	0/136 (0)	1.0
Safety Process Measures			
Unsuccessful Procedures	23/548 (4.2)	83/1,159 (7.2)	0.02
Ultrasound Use*	275/284 (96.8)	606/673 (90.0)	0.0004
Central Line	128/135 (94.8)	534/601 (88.9 %)	0.04
Thoracentesis	147/149 (98.7)	72/72 (100)	1.0
Femoral Venous	22/210 (10.5)	136/788 (17.3)	0.02
Catheterization			
Attending Involvement	544/548 (99.3)	661/1,159 (57.0)	<0.0001

*Ultrasound use for internal jugular and femoral venous catheterization and thoracentesis

ing participation; the remainder documented fellow (23.4 %, 95 % CI 19.8–27.0 %) or no senior clinician (29.5 %, 95 % CI 25.6–33.4 %) participation.

DISCUSSION

Our comprehensive review of over 1,700 consecutive bedside medical procedures represents the most extensive analysis of the impact of an MPS on patient safety to date. Overall, the MPS was consulted to perform 32.1 % of all bedside procedures. Major complications were rare, occurring in 1.8 % of bedside medical procedures. Most (74 %) major complications were associated with CVC placement. While procedures performed by the MPS were significantly more likely to be successfully completed and performed using best practice safety process measures, we found no difference in the rate of major complications between procedures performed by the MPS and primary services.

We were surprised by the similar procedural complication rates of the MPS and the primary services. One possible explanation is that residents who are uncomfortable or less experienced performing procedures, and thus would be more likely to experience complications, may preferentially refer their procedures to the MPS, thus biasing the results towards the null. Another possibility is that residents may have preferentially referred patients with a higher risk of complications to the MPS, while performing procedures themselves on patients with a lower anticipated risk of

complications. Unfortunately, given the small number of complications on both services and the multiple patient-related, procedure-related, and operator-related factors that confer increased risk of complications, we could not fully explore the effect of these factors on outcomes.

Overall, the rates of major complications identified in our study are similar to those reported by other authors, and our study adds to a growing body of evidence that bedside procedures performed at teaching institutions may be safer than previously thought.^{1–5,15} In contrast to the historic “see one, do one, teach one” model of procedure supervision, we identified a high rate of senior clinician involvement in bedside procedures throughout the hospital. While the MPS was significantly more likely to document ultrasound use and to avoid femoral CVC, we identified an encouragingly high rate of compliance with these safety process measures on the primary services as well. This high degree of attention to procedure quality and safety throughout the medicine department may partially explain why we did not identify a difference in major complication rates overall between the MPS and primary services.

In contrast to the high rate of senior clinician involvement, the rate of resident participation in bedside procedures was lower than expected (documented for only 55.3 % of procedures). Although the MPS was developed as a tool to improve resident procedure education, resident participation was similar for procedures performed by the MPS and primary services. While attending involvement was significantly more likely in procedures performed by residents on the MPS, this improvement occurred at the cost of having more procedures on the MPS performed independently by attending physicians without any resident or fellow (26.6 % vs. 7.6 %, $p < 0.0001$)—a missed educational opportunity.

In light of strict Accreditation Council for Graduate Medical Education limitations on housestaff work hours, residents must prioritize how they will use their time.¹⁶ In July 2007, the American Board of Internal Medicine (ABIM) revised the requirements for graduation from internal medicine residency programs, no longer requiring documentation of a specific number of supervised bedside medical procedures.¹⁷ Graduating residents are now required only to demonstrate understanding of procedure indications and contraindications, identification and management of procedural complications, and interpretation and handling of specimens. Even prior to this decision, the number and variety of procedures performed by internists already appeared to be decreasing, and many internal medicine residents were graduating without demonstrating competency in performing bedside procedures.^{1,2,18,19} The ABIM’s decision likely deprioritized obtaining proficiency in performing procedures even further, such that now only the most motivated residents seek to master this skill. Indeed, the fact that residents deferred half of all bedside procedures performed during weekdays—including many performed in the ICU (the traditional venue for mastering procedural skills)—to the MPS suggests that

learning to perform these procedures may not be a top priority for housestaff, who undoubtedly have multiple competing demands on their time.

The results of our study should remind the medical education community that the development of a MPS in and of itself does not ensure that resident opportunities to gain hands-on procedural experience will increase. Even if residents opt to spend a 2-week elective on the MPS, it is unrealistic to assume that those who pass up the opportunity to perform bedside procedures on their own primary service patients will be able to gain mastery in performance of all bedside procedures. While simulation can improve procedural skills, such curricula are designed to supplement—not replace—hands-on training.^{20–23} The implication is that the percentage of practicing internal medicine physicians who are not proficient at performing or supervising bedside procedures is likely to increase. Hence, the demand for specialized procedure services will likely expand in the future as hospitals struggle to ensure that procedures can still be performed 24 h per day.

Irrespective of implications related to patient safety and resident education, the development of a MPS has financial implications. At Boston Medical Center, the MPS is staffed by pulmonary and critical care attendings who have no other clinical responsibilities when they staff the MPS. Since the MPS performed an average of two procedures per day, the revenue generated by a MPS attending is lower than the amount the same clinician could generate spending the day staffing pulmonary clinic or the ICU. Other MPS models that do not remove the supervising attending from other revenue-generating activities may be more cost-effective. To augment revenue while meeting an institutional need, our MPS has recently begun performing PICC placement. While potentially lucrative, this practice will likely further detract from resident procedural training opportunities.

Like all studies based on retrospective chart review, this study has limitations. We were limited in our ability to assess characteristics and complications of procedures by the extent to which they were documented in the medical record. We could not reliably discern important characteristics that would confer a higher risk of complications and a lower likelihood of using best practice safety process measures, such as clinical instability at the time the procedure was performed or emergent indications. We did not have sufficient confidence in the accuracy of clinician self-report of certain safety process measures (e.g., number of punctures) or on safety outcomes such as minor complications (e.g., inadvertent arterial puncture) to report these data. Similarly, it is likely that rates of unsuccessful procedures (which are self-reported) are underestimated. However, we believe that self-report of unsuccessful procedures would, if any bias existed, be more likely to occur by procedure service attendings (who are incentivized

to document unsuccessful procedures, because they can still bill for them), as opposed to unsuccessful procedures performed by other services, which were more likely to be performed in the absence of attending supervision and would therefore be ineligible for billing. In addition, while we assume that residents participating in procedures would ensure that the procedure note reflects their involvement, it is possible there is under-documentation of resident participation. Finally, while procedure notes document attending and resident participation in bedside procedures, they provide limited information about the degree or quality of each participant's involvement. It is possible that although the proportion of resident involvement in bedside procedures was similar between the MPS and the primary services, the quality of the educational experience differs in ways our study was unable to elucidate.

In conclusion, we found that at a large academic medical center, the MPS did not achieve the goals of reducing major complications of bedside medical procedures or improving resident procedural training opportunities. If internal medicine residency programs are to continue to ensure that residents have the opportunity to gain competence in such procedures, a multimodal approach to procedure training that includes both alternative educational modalities, such as simulation and hands on-procedural experience supervised by dedicated proceduralists, may be necessary.

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