


Medical Procedure Services in Internal Medicine Residencies in the US: a Systematic Review and Meta-Analysis



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BACKGROUND AND AIMS: The number of procedures performed by internal medicine residents in the United States (US) is declining. An increasing proportion of residents do not feel confident performing essential invasive bedside procedures and, upon graduation, desire additional training. Several residency programs have utilized the medical procedure service (MPS) to address this issue. We aim to summarize the current state of evidence by systematically evaluating the effect of the MPS on resident education, comfort, and training, as well as patient safety and procedural outcomes in the US.

METHODS: We conducted a systematic review of all studies reporting the use of an MPS with supervision from a board-certified physician in internal medicine residencies in the US. Database search was performed on PubMed, Embase, ERIC, and Cochrane Library from January 2000 to November 2020 for relevant studies. Quality of evidence assessment and random-effects proportion meta-analyses were performed.

RESULTS: A total of nine studies reporting on 3879 procedures performed by MPS were identified. Procedures were safely performed, with a pooled complication rate of 2.1% (95% CI: 1.0–3.5) and generally successful, with a pooled success rate of 94.7% (95% CI: 90.8–97.7). The range of procedures performed by residents under MPS was 6.7–72.8 procedures per month ($n = 9$) compared to 4.3–64.4 procedures ($n = 4$) without MPS. MPS significantly increased confidence, comfort, and use of appropriate safety measures among residents.

CONCLUSION: There are a limited number of published studies on MPS supervised by a board-certified physician in US internal medicine residencies. Procedures performed by MPS are generally successfully completed and safe. MPS benefits internal medicine residents training by improving competency, comfort, and confidence.

KEY WORDS: meta-analysis; systematic review; medical procedure service; teaching; internal medicine residency.

Abbreviations

MPS Medical procedure service
US United States

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INTRODUCTION

Procedural training is an essential component of internal medicine residency and board-certified physicians are expected to be competent in invasive bedside procedures.¹ Yet, an increasing number of residents do not feel confident performing core procedures, such as thoracentesis, paracentesis, lumbar puncture, and central venous catheterization.² Education of physicians-in-training on bedside procedures has been shown to decrease preventable adverse outcomes³ and reduce the proportion of residents seeking additional training.⁴

Lack of supervision is the most commonly reported reason behind resident discomfort and dissatisfaction regarding their procedural training.⁵ Multiple interventions have been piloted to address training deficiencies. The first published account of a Medical Procedure Service (MPS) was from Beth Israel Deaconess Medical Center (Boston, MA) in 2002.⁶ MPS is an educational service where residents perform inpatient bedside procedures under the supervision of a board-certified physician. The use of MPS has subsequently spread to residency programs across the United States (US).⁶

It is hypothesized that an MPS improves patient safety and standardizes the approach to teaching, performing, and evaluating medical procedures. Yet, studies evaluating MPS procedural outcomes and the benefits on the procedural training of residents are limited. The aim of this systematic review is to characterize the types of procedures, safety profile, and educational benefit of MPS in US internal medicine residencies.

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METHODS

Study Design

The systematic review was conducted in accordance with the guidelines by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Appendix 1).⁷ The protocol was registered prospectively with the International Prospective Register of Systematic Reviews (PROSPERO 173296).

Full texts and abstracts published in English after January 1, 2000, that reported the utilization of an MPS supervised by a board-certified physician in internal medicine residency programs in the US were considered eligible. Exclusion criteria included (i) non-English articles, (ii) studies structured without supervision of a board-certified physician, (iii) studies reporting on procedures in the outpatient setting, (iv) studies enrolling residents outside the US or in US residency programs other than internal medicine, (v) reviews (narrative or systematic) and meta-analyses, (vi) *in vitro*, animal, or genetic studies without any primary data, and (vii) book chapters, letters to the editor, errata, comments, perspectives, editorials that did not provide any primary data.

Data Collection and Outcomes

A standardized, pre-piloted form was used to extract data from the included studies. Two reviewers (MHH, MHM) extracted the data independently, and any disagreements were identified and resolved through quality control discussions with another author (KGB).

The outcomes of interest were the demographics of the residency program; level of training of the residents and supervising board-certified physician participating in the MPS; duration and structure of the MPS; duration of the study; presence and results of pre- and post-rotation competency; confidence assessments of residents on the MPS; scale used to measure resident's self-perceived knowledge and confidence; and success rate, complication rate, and type of complications of procedures performed by residents on the MPS. A successfully performed procedure was defined as having been completed during a single continuous attempt, regardless of the number of sites or procedure kits used.

Search Strategy

The search was carried out in PubMed, Cochrane, ERIC, and Embase (last search date: November 7, 2020). The search employed the following algorithm: "procedure training" OR "procedure service" OR "procedure teaching" OR "procedure education" OR "procedure elective" OR "teaching procedure" OR "bedside procedure" OR "medical procedure" OR "resident procedure" OR "procedural service" OR "procedural training" OR "procedural education" OR "procedural teaching" OR "procedural elective." Reference lists of the eligible studies were also systematically searched for relevant, potentially missed articles using the "snow-ball" approach.⁸ Two

reviewers (MHH, MHM) independently screened the titles and abstracts, and then the full texts by applying the abovementioned inclusion and exclusion criteria. Disagreements were resolved through discussion with a third reviewer (KGB).

Quality of Evidence Assessment

The methodological quality assessment was performed independently by two reviewers (MHH, KGB), using the Downs and Black scale (Appendix 2).⁹ For the assessment of the observational studies, an adaptation was performed, as suggested by the Cochrane Collaboration, excluding items related to experimental studies (7, 9, 14, 15, 16, 17, 24, 26, 27) because they did not fit the methodological design of the analyzed studies. Studies were classified as having high methodological quality when they presented scores $\geq 70\%$ on the scale (15 points).

Statistical Analysis

Categorical variables were summarized as frequencies and percentages with the respective 95% confidence intervals (CI), and continuous variables as ranges. All relative rates were estimated based on available data for each variable of interest, and available data were handled according to the Cochrane Handbook principles.¹⁰

As most studies did not report on a comparison group, we conducted meta-analyses of proportions to calculate the pooled success rate and the total, lumbar puncture, paracentesis, thoracentesis, and central venous catheterization complication rates under MPS. Since the proportions in some studies were close to or exactly 0 or 1, we transformed them into quantities according to the Freeman-Tukey variant of the arcsine square root-transformed proportion; otherwise, these studies would be excluded from the analysis, which would lead to a biased pooled estimate.¹¹ Then, the pooled proportion was calculated as the back transformation of the weighted mean of the transformed proportions, using the random-effects model to account for potential between-study clinical heterogeneity and to adopt a more conservative approach. The respective 95% CI and the *p* values were also calculated for each outcome. We assessed statistical heterogeneity among the included studies using I^2 .¹² All analyses were performed using Stata IC 16.0 (StataCorp LLC, College Station, TX).

RESULTS

Study Selection and Characteristics

The search yielded 5684 articles, 13 of which underwent full-text review. Nine studies (six full texts and three abstracts) were ultimately included in the systematic review. Six studies were rated as high methodological quality^{4,6,13–16} and three studies were rated as low methodological quality.^{17–19} Six studies reporting success or complication rates were included in the meta-analysis in the meta-analysis (Fig. 1).

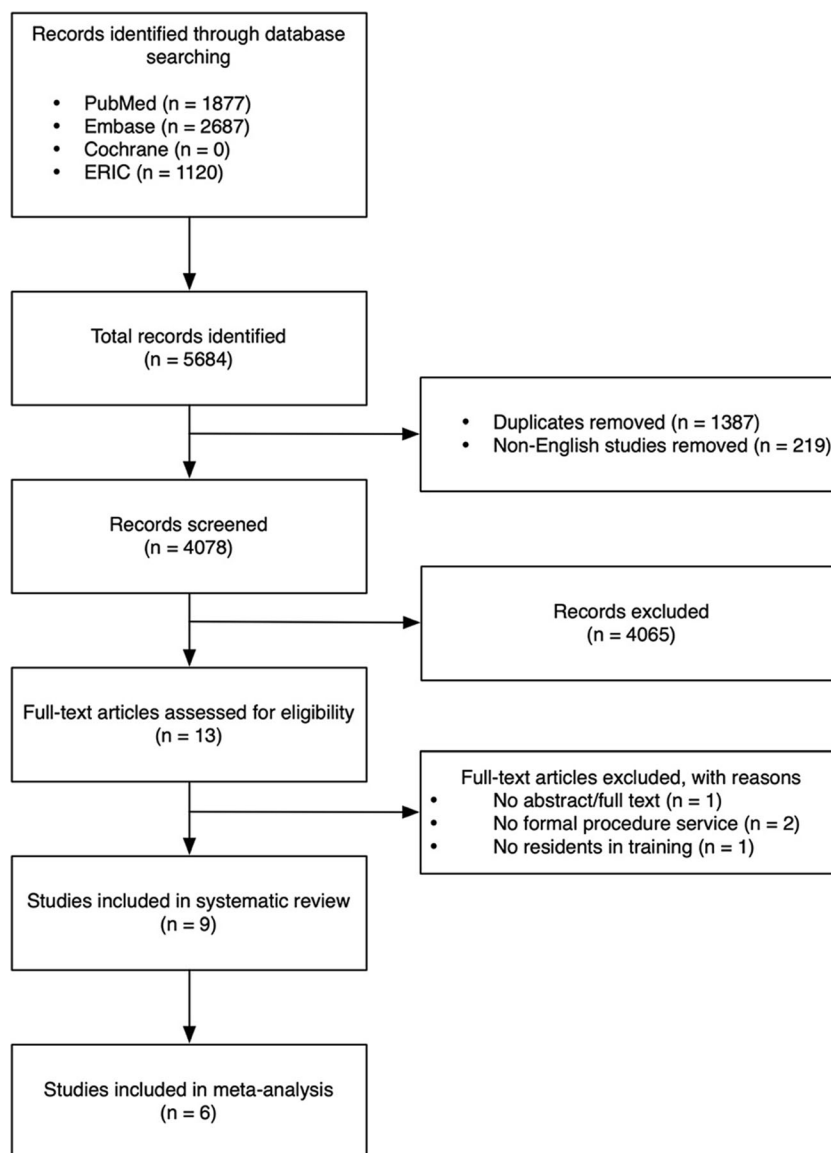


Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) flow diagram of the search strategy and study selection.

Seven studies^{4,6,13–16} were carried out in university-based or university-affiliated academic programs. The MPS by Montuno et al.¹⁴ was part of a community residency program and Schmit et al.¹⁷ did not comment on the affiliation of their residency program. The study duration ranged between 3 and 48 months ($n = 9$). Table 1 summarizes the characteristics of the selected studies.

Structure of MPS

All studies enrolled internal medicine residents and one study⁴ also had participating medicine-pediatrics residents. The time that residents rotated on the MPS ranged between 2 and 4 weeks ($n = 8$). The number of residents per service ranged between 1 and 3 ($n = 3$).^{4,6,16} Board-certified instructors were pulmonary and critical care attendings or internal medicine hospitalists with specialized training in procedures. The board-

certified physician in one study was a chief resident,¹⁷ while an advanced practitioner was present in addition to the board-certified physician in another study.¹⁸

Resident education was supplemented with standardized didactic and simulation-based training in five studies using videos, three-dimensional models, and simulator-based practice.^{4,6,26,10,12} The didactics reviewed the indications, contraindications, risks, and benefits of all procedures, and basics of ultrasonography. Formal assessment after the supplemental training was conducted to assess the procedural competence of residents before performing bedside procedures on patients in three studies.^{6,15,17}

MPS Procedures

All MPS supervised non-urgent procedures, while one study⁶ additionally included urgent procedures. Supervision was

Table 1 Participant Characteristics in the Medical Procedure Service

Study	Duration of study (months)	Duration of MPS (weeks)	Board-certified physician supervisor	Total number of residents enrolled in study	Procedures performed by MPS
Smith 2004	12	4	PCCM attending hospitalist	139 IM residents	Non-emergent and urgent LP, PC, TC, CVC
Lucas 2007	2	2	Hospitalist	16 IM residents	Non-emergent LP, PC, TC, AC, CVC
Lenhard 2008	11	2	PCCM attending hospitalist	36 IM residents 3 medicine-pediatrics 1 resident: NR	Non-emergent LP, PC, TC, CVC
Mourad 2012	8	2	Hospitalist	16 IM residents	Non-emergent LP, PC, TC, CVC
Chang 2012	3	2	Hospitalist	NR	Non-emergent LP, PC, TC
Schmit 2012	5	4	Chief resident	NR	Non-emergent LP, PC, TC, CVC
Tukey 2014	18	2	PCCM attending hospitalist	NR	Non-emergent LP, PC, TC, CVC
Bakhru 2015	24	NR	PCCM attending advanced practitioner	NR	Non-emergent LP, PC, TC, CVC
Montuno 2016	48	4	PCCM attending hospitalist	63 IM residents	Non-emergent LP, PC, TC, CVC

Pulmonary and critical care medicine (PCCM); internal medicine (IM); thoracentesis (TC); paracentesis (PC); lumbar puncture (LP); central venous catheterization (CVC); not reported (NR)

offered for thoracentesis, paracentesis, lumbar puncture, and central venous catheterization in all studies, with the exception of one study,¹⁷ where central venous catheterization was not performed. One study⁴ also included supervised bedside arthrocentesis on the MPS. No study included the supervision of ultrasound peripheral vein cannula insertion, peripherally inserted central catheterization, nasogastric tube insertion, or surgical chest tube placement.

The number of procedures performed by residents under MPS ranged between 6.7 and 72.8 procedures per month ($n = 9$). The number of procedures performed by residents without access to the MPS ranged between 4.3 and 64.4 procedures per month ($n = 4$).^{13,15,16,19} All studies reported that residents performed more procedures independently after completing the MPS.

Three studies^{13,14,19} reported the number of procedures performed by residents before and after rotating on the MPS. In the study by Montuno et al.,¹⁴ there were 4.3 procedures performed per month in the pre-MPS group vs. 6.7 procedures per month in the post-MPS group ($p < 0.001$). Chang et al.¹⁹ showed an increase in the number of procedures performed per month: 6.3 procedures per month pre-MPS vs. 34.7 procedures per month post-MPS implementation. In the crossover study by Lucas et al.,¹³ the availability of the MPS increased the number of procedures from 61 to 90 procedures performed per 1000 admissions ($p = 0.03$), and after crossover, the residents who lost the ability to utilize the MPS had a non-statistically significant drop in the number of invasive procedures they attempted independently.

Two studies reported findings of a MPS group and comparable control group.^{15,20} In the randomized control trial by Mourad et al.,¹⁵ the MPS group performed more thoracenteses (median: 6 vs. 2; $p < 0.001$), paracenteses (median: 9 vs. 4; $p < 0.001$), and lumbar punctures (median: 4 vs. 3; $p < 0.001$) compared to the control group. Similar findings were reported by Tukey et al.,¹⁶ for thoracenteses (149 vs. 72; $p < 0.001$), but

the regular service performed more paracenteses (127 vs. 163; $p < 0.0001$), lumbar punctures (62 vs. 136; $p < 0.0001$), and central venous catheterizations (210 vs. 788; $p < 0.0001$).¹⁶

Procedure Success Rates

The success rate of procedures was reported by four studies.^{13,16–18} The pooled success rate for all procedures was 94.7% (95% CI: 90.8%–97.7%; $I^2 = 89.75%$) (Fig. 2a). Two studies compared the success rate between residents with and without access to the MPS. In the study by Tukey et al.,¹⁶ MPS residents successfully completed more procedures (95.8% vs. 92.8%; $p = 0.02$) and practiced better safety measures, including use of ultrasound guidance when appropriate and avoidance of femoral venous catheterization. In contrast, Lucas et al.¹³ reported no difference in the proportion of procedures completed successfully by residents where the MPS was available for consultation (67% vs. 49%; $p = 1.00$) or for procedures with direct observation from the MPS physician (43% vs. 73%; $p = 0.64$) compared to procedures where the MPS was not available.

Procedure Complications

The total complication rate for procedures performed by the MPS was reported in five studies (Table 2).^{6,13,15,16,18} The pooled total complication rate was 2.1% (95% CI: 1.0–3.5%; $I^2 = 72.79%$) (Fig. 2b). Three studies^{13,15,16} had no difference in the composite rate of major complications between MPS and regular service group. Two studies^{6,18} noted that procedures under MPS had complication rates consistent or lower than that reported in literature.^{20,21} All studies stated that the MPS resulted in an increase in the use of best practice safety measures.

Under MPS, lumbar punctures had the lowest complication rate with a pooled complication rate of 0.0% (95%

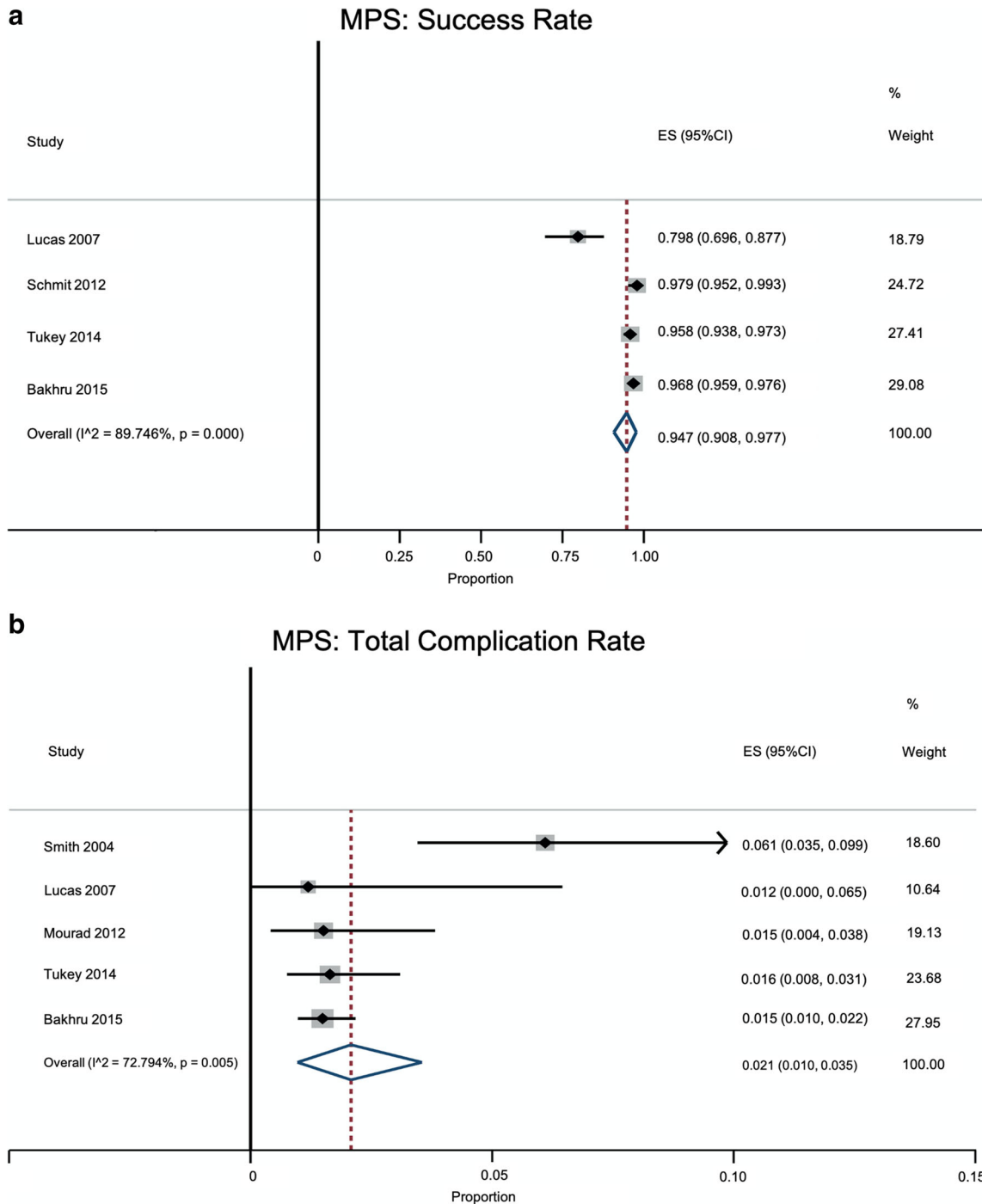


Figure 2 Forest plots reporting the pooled success rate (a), total complication rate (b). Random-effects modeling of pooled rates was used for the meta-analysis of proportions with 95% confidence intervals.

CI: 0.0–1.3%; $I^2 = 00.00\%$) (Fig. 3a).^{6,13,15,16} Paracentesis had the highest pooled complication rate of 2.3% (95% CI: 0.1–6.6%; $I^2 = 62.21\%$) (Fig. 3b).^{6,13,15,16} The pooled complication rate was 1.9% (95% CI: 0.1–5.2%; $I^2 = 59.16\%$) for thoracentesis (Fig. 3c)^{6,13,14,16} and 1.9% (95% CI: 0.0–6.9%; $I^2 = 58.80\%$) for central venous catheterization (Fig. 3d).^{6,13,15,16}

Two studies^{6,20} provided qualitative data on complications. Pneumothorax was the most commonly encountered complication during thoracentesis, accounting for 71.4%⁶

and 66.7%¹⁶ of complications and resulting in an iatrogenic pneumothorax rate of 3.3%⁶ and 4.0%.¹⁶ Other less commonly encountered complications included hematoma, hemothorax, and infection. For paracentesis, hemorrhage was the most common complication, followed by failure to obtain ascitic fluid and kinking of the catheter.^{6,16} For lumbar punctures, Tukey et al.¹⁶ did not report any complications, while venous blood return requiring blood transfusion was the only complication reported by Smith et al..⁶

Table 2 Procedures Performed Under MPS and Their Respective Complications

Study	Total number of procedures, N	Total complications, n (%)	Number of LP, N	LP complications, n (%)	Number of PC, N	PC complications, n (%)	Number of TC, N	TC complications, n (%)	Number of CVC, N	CVC complications, n (%)
Smith 2004	246	15 (6.1%)	29	1 (3.4%)	37	4 (10.8%)	123	6 (4.9%)	57	4 (7.0%)
Lucas 2007	84	1 (1.1%)	10	0 (0.0%)	30	0 (0.0%)	28	0 (0.0%)	16	1 (6.3%)
Lenhard 2008	325	NR	69	NR	69	NR	73	NR	109	NR
Mourad 2012	265	4 (1.5%)	66	0 (0.0%)	122	4 (3.3%)	77	0 (0.0%)	29	0 (0.0%)
Chang 2012	104	NR	23	NR	62	NR	11	NR	5	NR
Schmit 2012	238	NR	37	NR	135	NR	51	NR	Not performed	-
Tukey 2014	548	9 (1.6%)	62	0 (0.0%)	127	1 (0.8%)	149	6 (4.0%)	210	2 (1.0%)
Bakhr 2015	1746	26 (1.5%)	484	NR	448	NR	498	NR	316	NR
Montuno 2016	323	NR	NR	NR	NR	NR	NR	NR	NR	NR

Thoracentesis (TC); paracentesis (PC); lumbar puncture (LP); central venous catheterization (CVC), medical procedure service (MPS), not reported (NR)

Residents Confidence, Self-Perceived Knowledge, and Perspective

Two studies reported on the confidence of residents performing bedside procedures before and after participation in the MPS.^{4,15} Residents in both studies felt significantly more confident after the MPS. In the study by Lenhard et al.,⁴ the proportion of residents who felt comfortable increased by 15–36% for thoracentesis, paracentesis, lumbar puncture, and subclavian central line catheterization after participation in the MPS. Mourad et al.¹⁵ utilized a 5-point Likert scale and pre-MPS and post-MPS scores demonstrated an overall increase in confidence ($p < 0.036$) for thoracentesis (2.1 vs. 4.5 points), paracentesis (3.1 vs. 4.7 points), lumbar puncture (1.8 vs. 4.4 points), and central venous catheterization (1.8 vs. 2.9 points). Both before and after the MPS, residents felt least comfortable with central venous catheterization and most comfortable with paracentesis.

The same two studies^{4,15} reported on resident self-perceived knowledge prior to and after participation in the MPS. Residents in both studies rated their self-perceived knowledge higher after the MPS. Lenhard et al.⁴ used a five-point Likert scale to assess self-perceived knowledge on the use of ultrasound, sterile techniques, insertion technique, indications, complications, and management of complications. The median score increased by one point after the MPS ($p < 0.001$). Similarly, the resident self-perceived knowledge after the MPS in Mourad et al.¹⁵ was higher post-MPS than pre-MPS ($p < 0.022$) in the same categories, with troubleshooting as an additional category assessed.

Furthermore, Lenhard et al.⁴ reported that the desire for additional training among residents decreased by 26–51% depending on the type of procedure after the MPS rotation. Smith et al.⁶ found that of the residents who rotated on MPS, 87% felt that the MPS improved their knowledge of medical procedures, 90% believed the MPS helped prevent complications, and 83% rated the service as either time neutral or time saving. In two studies,^{4,15} the improvements seen in the knowledge, performance, and certification of residents after the MPS persisted into the next year of residency.

DISCUSSION

The MPS consisted of a hospitalist or pulmonary and critical care physician supervising non-urgent thoracentesis, paracentesis, lumbar puncture, and central vein catheterization. The majority of MPS incorporated didactic education and practice using mannequins prior to performing procedures on patients.^{4,6,15,17,19} Procedures were safely performed, with a pooled complication rate of 2.1%, and generally successful, with a pooled success rate of 94.7%. All studies stated that the MPS resulted in an increase in the use of best practice safety measures.

Over the past 30 years, the number of procedures performed by general medical practitioners has significantly decreased.²²

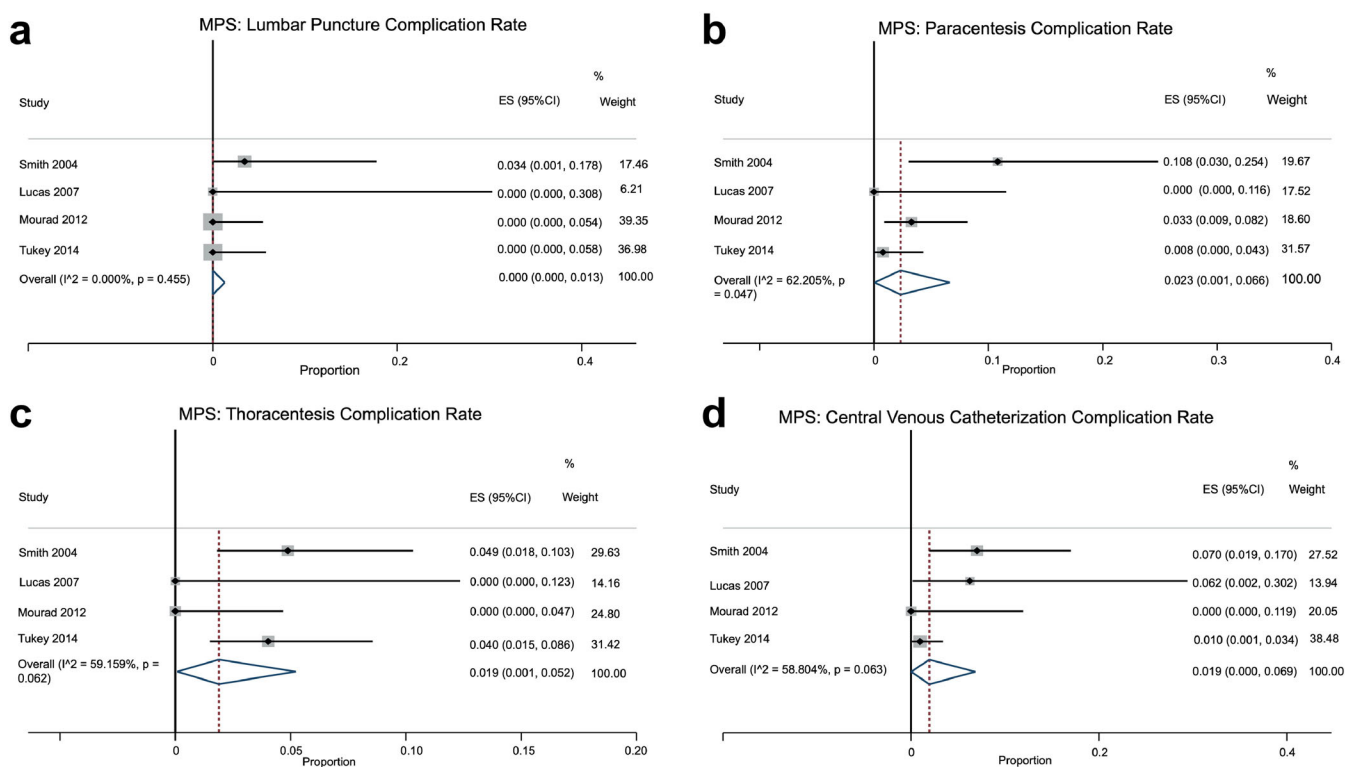


Figure 3 Forest plots reporting lumbar puncture (a), paracentesis (b), thoracentesis (c), and central venous catheterization complication rates (d). Random-effects modeling of pooled rates was used for the meta-analysis of proportions with 95% confidence intervals.

Effective 2007, the American Board of Internal Medicine removed the minimum requirement for the number of procedures performed by residents for board certification.²³ Nine years later, Kay et al.²⁴ reported that 84% of procedures encountered on a general medicine service at an academic medical center were referred and performed by a hospitalist or interventional radiologist.

The traditional “do one, see one, teach one” training model for procedures is a source of discontent among residents and program directors.²⁵ Direct supervision has been shown to decrease procedural discomfort and the utilization of MPS as an educational tool for residents may represent a potential solution.^{5,26} All four studies that qualitatively assessed the educational experience of residents reported an increase in confidence and self-perceived knowledge.^{4,6,15,16} There is a growing body of evidence to support an increase in the number of procedures, certification rates,^{14,16} and overall procedural competence^{6,15} in residents participating in an MPS. Direct procedural supervision has also been linked to a reduction in complications.^{3,27} The pooled complication and success rates for procedures performed by MPS were favorable compared to previous studies without MPS.^{24,28} Additionally, MPS led to an increase in the number of procedures performed by residents without an increase in complications. However, the results on risk reduction rates were discordant among the included studies.

To our knowledge, our study is the first systematic review to characterize the types of procedures, safety profile, and educational benefit of an MPS supervised by a board-certified physician in US internal medicine residencies. As procedural competency and training requirements vary significantly between residents in internal medicine and non-medical specialties, as well residents training in and outside the US, the inclusion and exclusion criteria were purposely designed to capture all studies from US internal medicine residencies. Our conclusions are consequently more specific, applicable, and likely to catalyze change within internal medicine residency programs across the US.

Limitations of our review include the retrospective nature of the majority of included studies, which impart a degree of inherent selection bias. There was considerable interstudy heterogeneity in study design, where only two studies included a contemporaneous control group^{15,16} and two other studies reported pre-MPS and post-MPS implementation outcomes.^{14,19} In addition, the subjective measurements of comfort and self-knowledge may not reflect competence.^{2,29} Finally, our analysis grouped residents into one cohort due to the low number of included studies in our systematic review; our results do not assess the differences in procedural performance, comfort, and self-knowledge in relation to the resident training level.

With only nine studies meeting criteria for inclusion, the systematic review highlights the need for further research in

this field. Future research should focus on additional factors that could be contributing to the broad uptake of MPS in US internal medicine residencies, the cost-effectiveness of MPS for procedural education, and an assessment of the durability of benefits derived from MPS.

CONCLUSION

There are limited published studies on MPS supervised by a board-certified physician in US internal medicine residencies. Procedures performed by MPS are generally successfully completed and safe. Procedural supervision by MPS results in an increase in the use of best practice safety measures. MPS benefits internal medicine residents training by improving competency, comfort, and confidence.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11606-020-06526-2>.

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Compliance with Ethical Standards:

All authors filled out a detailed Declaration of Interest Statement.

Conflict of Interest: The authors declare that they do not have a conflict of interest.

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