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Plan-do-study-act (PDSA) interventions to improve real-world endoscopy unit productivity

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ABSTRACT

Background and study aims The Plan-Do-Study Act (PDSA) ramp is a framework that uses initial small changes to build consensus and momentum for subsequent, iterative process improvement. Our aim was to study its impact on endoscopy unit efficiency and throughput.

Methods Following a granular time-and-motion analysis to evaluate baseline performance (phase 1) we instituted successive interventions and measured their impact on core efficiency metrics including procedure volume and turnover time (phases 2–3).

Results We identified that inefficiency in turnover of anesthesia-supported endoscopy was the most crucial issue. Implementation of a pre-procedure anesthesia visit in phase 2 reduced turnover time by 15.5 minutes (95% confidence interval 3.9–27.1 minutes). Subsequent changes (phase 3) including front-loaded procedure scheduling and parallel in-room preparation resulted in an 18% increase in procedure volume.

Conclusions The PDSA ramp model is an effective means of assessing operational processes, developing novel interventions, and building consensus to improve the real-world productivity in a resource-conscious manner.

Introduction

During and after the COVID-19 pandemic, staff shortages and mounting procedure backlogs exacerbated a preexisting shortage of endoscopy resources. In the previous two decades, widespread screening for gastrointestinal malignancies, an aging population, and reduced endoscopist training set the context for this shortfall [1, 2, 3]. The worldwide post-pandemic shortage of nurses and technicians remains problematic, particularly in safety-net (underserved) settings with limited resources available to support operations [4].

Operations analysis, including time and flow studies, emerged in the early 20th century to optimize manufacturing [5]. Despite widespread adoption in anesthesia and surgical settings, these strategies have only recently been introduced to endoscopy units (EUs) [6]. The Plan-Do-Study-Act (PDSA)

ramp cycle is a framework used to systematically introduce and implement changes for quality improvement and involves a stepwise process. The four steps are development of a proposed intervention (plan), implementation of this intervention (do), analysis of how the intervention affects outcomes (study), and then adaptation of the findings into practice (act). This cycle is then repeated with modifications to the intervention as needed. Interventions start small to prevent disruptions in opinion and workflow and are subsequently scaled or "ramped up" over time as support is gathered through proof of concept. Initial results encourage organizational consensus and stakeholder buy-in to the quality improvement (QI) initiative and support larger changes and operational improvements downstream (▶**Fig. 1**). We report the implementation of the PDSA ramp model to evaluate and improve EUs efficiency and productivity.

Methods

Setting

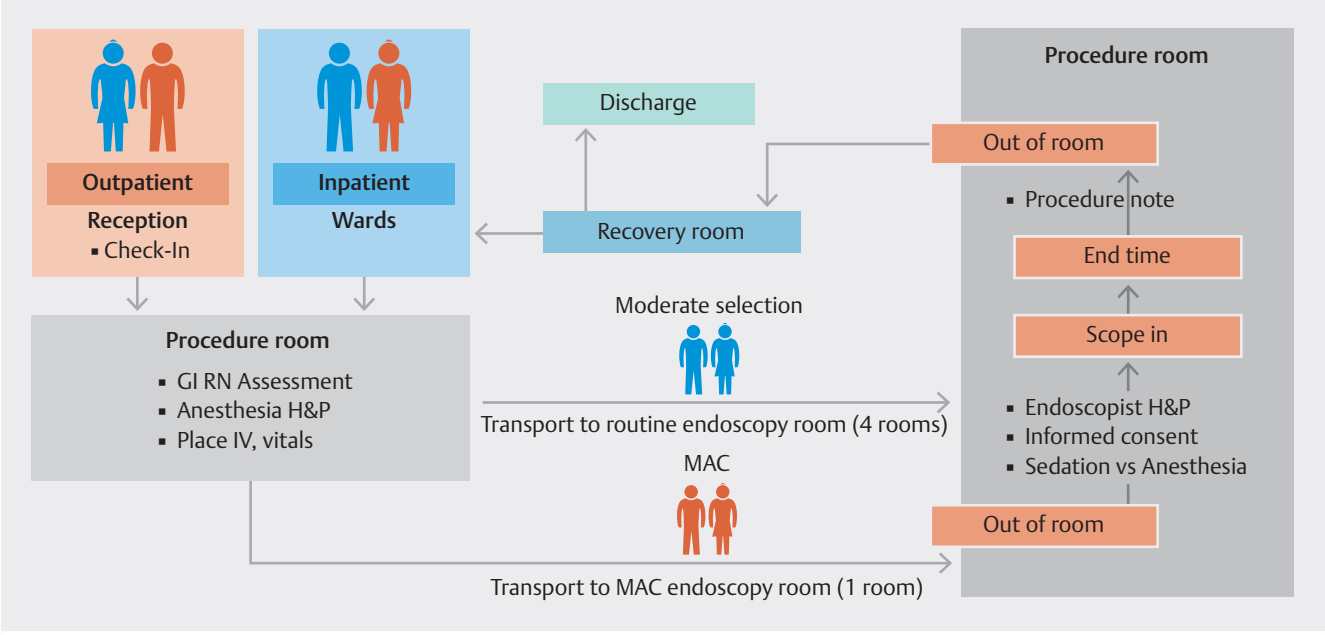
This study was conducted in the Los Angeles County University of Southern California (LAC+USC) Medical Center EU. Prior to initiation, it was approved by the University of Southern California Health Sciences Institutional Review Board. The EU has five endoscopy rooms and 90% of procedures are performed using moderate sedation. One day each week, one room is dedicated to monitored anesthesia care (MAC) procedures supported by a certified registered nurse anesthetist (CRNA). All endoscopies are performed by fellows under attending supervision. The EU is supported by an adjacent 12-bed pre-procedure/recovery unit (PPU).

Process-flow map and time-flow study

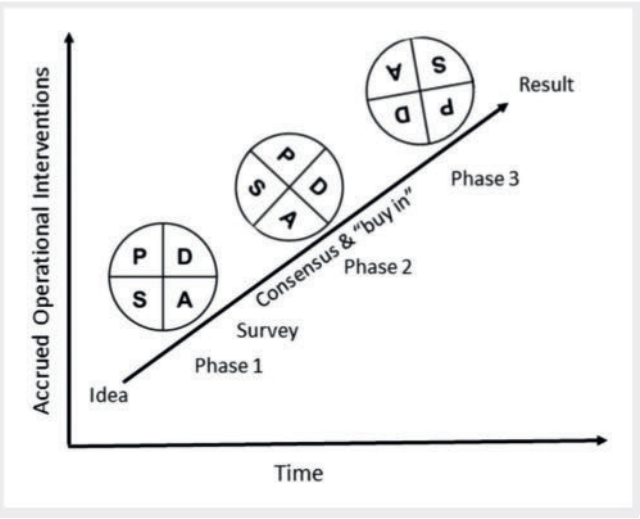
An initial EU process-flow map was created via observation of workflow and interviews with unit staff (▶**Fig. 2**). To record the patient journey through the EU, the process-flow was transferred to a timesheet and attached to the patient chart. Unit or study staff manually recorded the time when each step was initiated and concluded. (**Supplementary Fig. 1**). A separate flow sheet was used for MAC cases to account for additional steps involved. Data were collected weekly for all procedures in each standard procedure room. For MAC procedure days, data were collected on the same day each week. Time points were cross-checked against mandatory "scope tracking logs," including time of patient entry to procedure room, procedure start time, scope exit time, and time of patient exit from procedure room (**Supplementary Fig. 1**). Overall procedure volume was aggregated from the electronic medical records (EMRs) by EU administrative staff and included both MAC and non-MAC days for all rooms.

Phases of the PDSA cycle

Three phases were designated. Phase 1 was observational, aimed at establishing baseline performance and identifying areas for intervention (▶**Fig. 1**). A multidisciplinary team (MDT) of study staff, endoscopy nurses, QI staff, physicians, and anesthesiologists reviewed data against established benchmarks [7, 8] and proposed interventions aimed at improving efficiency and throughput. The aim was to include all key stakeholders (nurses, endoscopists, anesthetists, and administrators) in decision making to obtain the perspective and buy-in of these groups. The entire medical team of the EUs was provided with a survey about perceived operational inefficiencies to better help identify areas of intervention. Although some is-



▶**Fig. 1** A diagram of the patient flow through the endoscopy unit (EU) from check-in to discharge.



▶ **Fig. 2** The Plan-Do-Study-Act (PDSA) ramp model process began in phase 1 with a baseline analysis of the endoscopy unit to identify inefficiencies in the workflow. Targeted interventions were developed between phases 2 and 3 and their effect analyzed between phases. Promotion of consensus and buy-in during the process allows for progressively greater operational interventions to be achieved over time.

sues, such as additional staff or equipment, could not be addressed due to cost containment constraints, other intervenable domains, such as room turnover time and late first case start time, were identified. Generally, perceptions of operational inefficiencies correlated well with deficiencies seen in comparison to established benchmarks. The combination of objective and subjective data allowed us to quickly implement interventions using the PDSA ramp model (▶ **Fig. 1**).

Phase 2 involved implementing the first targeted intervention, the utilization of a pre-anesthesia clinic (PAC) visit, to address two major deficiencies identified in Phase 1, excessive turnover time and low throughput through the MAC room. This required collaboration with our anesthesia colleagues to help set up a new workflow to include the PAC prior to endoscopy. To help acclimate staff to these new changes, a process-flow map was provided to each staff member to graphically describe the new pathway. At the end of Phase 2, we studied or reviewed the impacts of our primary intervention and found significant improvement in MAC room turnover time and throughput. It was initially difficult to motivate staff to engage in the proposed changes. Once we were able to demonstrate proven and measurable outcomes, we were able to gain stakeholder and staff support to enact larger and broader changes. In Phase 3, we enacted multiple simultaneous interventions to further improve the efficiency of the EUs (see results section). At the end of this cycle, impacts of all primary and secondary interventions were measured to determine their impact.

Main (productivity) outcomes

The primary outcome of interest was monthly total (anesthesia-supported MAC and non-MAC) procedure volume performed in the EU pre- and post-Phase 2 intervention. A co-primary productivity outcome was the daily volume of procedures in the MAC room following phases 2 and 3.

Operational metrics/outcomes

Outcomes included "turnover time," which was defined as the interval between a patient exiting the procedure room and entry of the next patient, "procedure end-to-room exit time," the interval between endoscope removal and patient egress from the procedure room and "in-room-to-procedure-start time," the interval between patient entry to procedure room and endoscope insertion. "First case on-time start" was defined as the proportion of cases in which the endoscope had been inserted by 08:00.

Statistical analysis

We calculated means (standard deviations/confidence intervals [CIs]) for continuous variables with normal distribution and medians (interquartile ranges) for nonparametric distributions. To compare baseline (Phase 1) metrics versus benchmarks we used one-sample *t*-tests for continuous (room turnover time, in-room-to-procedure-start time, procedure time, procedure end-to-room-exit time) and one-sample test of proportions for categorical variables (first case on-time start).

To compare the continuous productivity outcomes (main outcomes of the study) of total monthly procedure volume and daily MAC volume we used linear regression. Sensitivity analysis of total volume excluding March (as interventions were implemented mid-month) was performed. For the operational outcomes of room turnover time, procedure-end-to-room-exit time, in-room-to-procedure-start time) we used linear regression. For the continuous categorial operational outcome of first case on-time start we used logistical regression. Statistical analysis was performed using STATA 14.0 (College Station, Texas, United States).

Results

Patients

Prospective data were captured for 673 patients undergoing endoscopic procedures during the study period of 9 months divided between the phases. In Phase 1, 265 patients were evaluated to establish baseline metrics and derive primary interventions. During Phase 2, primary interventions were assessed for 167 patients. Phase 1 and 2 results were used to develop secondary interventions and assessed during Phase 3, involving 241 additional patients.

Population metrics versus benchmarks

Baseline analysis revealed mean turnover time of 45.3 minutes (95% CI 31.8–58.8) for MAC procedures exceeding the benchmark of 26.6 minutes. First case on-time start for both the MAC (20%) and moderate sedation rooms (29.3%) were below the benchmark of 64.5% (▶ **Table 1**). Other time measures for MAC procedures met benchmarks. For moderate sedation procedures, the time from procedure end to room exit was 16.5 minutes (95% CI 15.3–17.6) vs the benchmark of 9.4 minutes.

According to the stakeholder survey, room turnover time was the greatest perceived inefficiency in the EU (▶ **Fig. 3**).

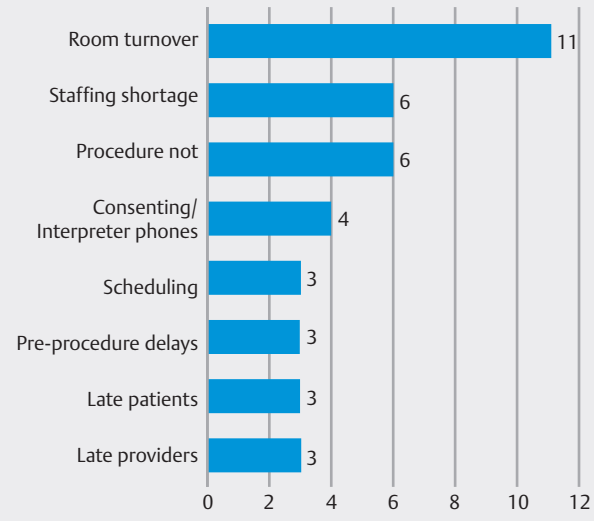
Identification and impact of first targeted intervention

Suboptimal throughput in the MAC room was designated as the first target for intervention. The MDT identified that delayed turnover was the rate-limiting factor to productivity, which was primarily a consequence of the need for patient evaluation on the day of the procedure by the anesthetist. To address this concern, the team recommended that all endoscopy patients scheduled for MAC procedures be referred to a PAC, which eliminated any inter-procedure anesthesia evaluations the day of the procedure by moving them to the day of endoscopy teaching (▶ **Table 1**). Standing appointments were created, allowing patients to visit the PAC immediately after their endoscopy teaching visit. In the PAC, history and physical assessment were performed and, if necessary, cardiac/biochemical tests ordered so that results were available in advance, rather than on the procedure day; it was thus a resource-neutral change. This was done at the same time as the required endoscopy teachings to further streamline efficiency. Following implementation, turnover time for the MAC room decreased by a mean of 15.5 minutes (95% CI 3.8–27.1) (▶ **Table 2**) and now aligned with established benchmarks. The daily anesthesia room volume from Phase 1 to 2 correspondingly increased from 5.6 (± 2.1) to 8.3 (± 2.1); mean difference 2.75 (95% CI 0.8–4.7) (▶ **Table 2**).

Definition of secondary interventions

Following Phase 2, the team devised additional interventions for implementation during Phase 3 (▶ **Fig. 2**, ▶ **Table 1**). The first MAC and moderate sedation patients of the day were prepared in the procedure room to directly bypass the pre-procedure unit and minimize transfer time. Daily procedure start times were recorded in a report card. In addition, a greater proportion of procedures were scheduled earlier in the day to mitigate the impact of patient no-shows, or delays due to unplanned (or excessively long) procedures or adverse events (AEs) (▶ **Table 1**).

To address late first procedure start and turnover, we instructed our team to prepare the first patients of the day in the procedure room to minimize transfer time and perform concurrent tasks for patient preparation throughout the day. Specifically, we asked our nurses to place intravenous lines and monitoring equipment (i. e. electrocardiogram leads, blood pressure cuffs, oxygen saturation monitors) while the endoscopists documented clinical history and obtained informed consent. A policy requiring procedure report completion before patient egress from the endoscopy room was identified as delaying procedure completion to room exit time. During Phase 3, this policy was modified such that only a very brief note and instruction by the endoscopists to guide care in the recovery room were required before egress from the procedure room.



▶ **Fig. 3** Results from an open-ended stakeholder survey sent to all EU staff, fellows, and faculty, that asked respondents to identify the most significant contributor to inefficiency in the EU.

Primary outcome: Endoscopy unit productivity

Post-interventions, the primary outcome of overall procedure volume per month increased from 495.8 (± 40.7) to 583 (± 73); mean difference 87.2 (95% CI 0.1–174) (▶ **Table 2**). In sensitivity analysis excluding March 2022 (changes implemented mid-month), this increased to 623.5 (± 29); mean difference 127.7 (95% CI, 49.8–205.6). In addition, the other main productivity outcome, mean number of daily MAC procedures, increased from 5.6 (± 2.1) to 9.6 (± 2.7) following Phase 2 and Phase 3 interventions: mean difference 4.0 (95% CI, 2.1–5.9).

Operations outcomes

The reduction in MAC turnover time was sustained at 30 minutes (± 24 minutes) in Phase 3, equal to the benchmark (▶ **Table 2**). In addition, there was an improvement in the first case on-time start percentage for the MAC room to 87.5% (odds ratio [OR] 28; 95% CI 2.6–297.9) and the moderate sedation room to 60% (OR 3.6; 95% CI 1.7–7.8). Procedure end-to-room-exit time decreased by 2.1 minutes (95% CI 0.8–3.3). There was a non-significant reduction in turnover time for moderate sedation procedures from 24.5 minutes (± 36.7) to 22 minutes (± 32.1).

Discussion

Time-flow and operations management approaches were introduced in healthcare to optimize operating room function [5, 6, 7, 8, 9]. Akin to surgery, innovative endoscopic technology has increased costs while reimbursements have been reduced, creating the need to improve efficiency [6]. With more than 20 million procedures performed annually, gastrointestinal endoscopy represents the highest volume procedure performed in ambulatory care centers in the United States and im-

▶ **Table 1** Comparison of baseline times at LAC + USC to benchmarks with possible causes and interventions.

	Monitored	Anesthesia care	P value		Moderate sedation	*P* value		
Metric	**LAC + USC**	**benchmark***		**LAC + USC**	**benchmark***		**Explanation**	**Interventions**
Room turnover time	45.3 (31.8–58.8)	26.6[1]	< 0.01*	25.2 (19.7–30.7)	26.6[1]	0.6	Anesthesia evaluations by CRNA performed between procedures	PAT clinic, Streamline inter-procedure processes
First case on-time start	9 (0%-26%)	64.5%[1]	< 0.01*	33 (20%-47%)	64.5%[1]	< 0.01*	Patient prep outside room Same-day anesthesia evaluation	Pre-op 1st patient in room Double schedule early cases First case delay log
In room to procedure start time	16.0 (12.5–19.4)	20.8[2]	< 0.01**	25.6 (23.2–27.9)	33.7[2]	< 0.01*	Benchmark met	None
Procedure time	31.6 (26.7–36.4)	38.4[2]	< 0.01**	36.6 (33.4–39.9)	31.1[2]	< 0.01*	Benchmark met	None
Procedure end to room exit time	12.4 (10.6–14.2)	13[2]	0.5	16.5 (15.3–17.6)	9.4[2]	< 0.01**	Detailed report required before patient leaves procedure room	Brief procedure note Re-time procedure note

*Tested for equality with benchmark mean or proportion at 95% confidence interval, significant P value signifies significant difference with benchmark, did not meet metric.
**Tested for equality with benchmark mean or proportion at 95% confidence interval, significant p value signifies significant difference with benchmark, performance exceeded metric.
LAC + USC, Los Angeles County University of Southern California; CRNA, certified registered nurse-anesthetist; PAT, pre-admission testing.
[1]*Day L, Belson D* Gastroenterol Res Pract 2015; 764153.
[2]*Kaushal, K, Chang K, Lee J* et al. Gastrointesti Endosc 2014; 79: 637–645.

proved efficiency has the potential to provide substantial benefit [1, 2]. This study demonstrated that the PDSA ramp model is effective at maximizing efficiency and productivity in a resource neutral manner.

Prior work to use data to improve EU operations has focused on single interventions and, in most cases, utilized simulated results over real-world data. Day et al used a time-motion analysis and discrete event simulation to propose changes that might improve efficiency including shorter procedure times (60 to 45 minutes), modified scheduling, and expanded human resources [10]. Nevertheless, simulation was the primary method of validation because testing interventions in a large patient population was considered unfeasible. Kaushal et al performed a prospective flow analysis to identify a small PPU as the bottleneck in their EU and responded to this by utilizing procedure rooms to prepare patients whenever available [11]. They demonstrated that this single change improved on-time procedure start by 51% and reduced overhead costs in a large subsequent cohort. Others have collected critical data about efficiency metrics to identify problems and used modeling and other systems approaches to propose solutions [12, 13, 14, 15, 16].

The success of the present study in implementing multiple interventions is credited to the PDSA ramp model, using carefully chosen, limited preliminary actions to gain stakeholder buy-in prior to enacting extensive changes as well as the use of a multidisciplinary team approach. Our study identified the importance of increasing anesthesia room productivity with time-flow analysis delineating turnover time as the primary problem. The MDT recognized that testing and evaluation by the anesthetist on the day of the procedure delayed patient flow and recommended evaluating patients in the PAC before their procedures. This intervention was chosen to generate agency in the project for EU personnel and correspondingly addressed the most reported cause of delays from the stakeholder survey. The success of this first intervention in the "ramp" empowered the intervention team and prompted support from EU staff to carry out more extensive interventions in later phases. Following this intervention, the mean number of procedures doubled during Phase 2, and was sustained during Phase 3. Other interventions such as strategies to prepare the first patient of the day in the procedure room, parallel processing, and booking cases earlier in the day were simultaneously implemented. Con-

▶ **Table 2** Core productivity and efficiency parameters before and after PDSA-guided intervention.

	Pre-intervention	Post-intervention	Major changes implemented*	Statistical significance
	mean (+SD)	mean (+SD)		mean difference (95% CI)
Total volume (per month)	495.8 (+40.7)	583.0 (+73)	All	87.2 (0.1 to 174)
Anesthesia room volume (per day)	5.6 (2.1)	8.3 (2.1)	Pre-anesthesia clinic visit (PAT)*	2.8 (0.9–4.7)
Room turnover time (MAC)(minutes)	45.3 (± 41)	29.8 (± 23.5)		15.5 (-3.9 to –27.1)
Room turnover time (Moderate sedation)(minutes)	24.5 (+36.7)	22.0 (+32.1)	Parallel patient preparation by RN and MD**, PAT*	–2.4 (–8.7 to 3.8)
Scope out to out of room (Moderate sedation)	16.5 (8.1)	14.4 (.6.8)	Brief procedure note**	–2.1 (–3.3 to -0.8)
	N(%)	N(%)	Phase	OR
First-case on time start % (anesthesia supported)	20%	87.5%	Pre-op 1st patient in procedure room**	28 (2.6–297.9)
First-case on time start % (moderate sedation)	29.3%	60.0%	Double schedule early cases to mitigate impact of no shows**	3.6 (1.7–7.8)

*Interventions implemented in Phase 2.
**Interventions implemented in Phase 3.
PDSA, Plan-Do-Study-Act; SD, standard deviation; CI, confidence interval; PAT, pre-admission testing; MAC, monitored anesthesia care.

sequently, in Phase 3, we confirmed a significant improvement in the operational outcomes of first case on-time start and turnover times. Of even greater importance, the PDSA process as a whole resulted in a significant improvement in the main outcome of interest, which was EU productivity. This was measured by the overall number of monthly procedures and the daily number of procedures in the resource-intensive room requiring anesthesia support.

In the current study, the multidisciplinary team (MDT) reviewed the data, crafted proposed interventions, and paired our acquisition of operational metrics with a stakeholder survey to define barriers to productivity. There are valid concerns that using quantitative information to guide operations may dehumanize clinical practice [17]. In contrast to top-down interventions, the use of a multidisciplinary team cognizant of local factors in the PDSA ramp model enables a nuanced approach that accounts for cultural and structural factors in the environment [11, 13]. Including nurses, endoscopists, anesthetists, and administrator not only provides broad perspective for the group but facilitates dissemination and improves the willingness of the entire medical team to carry out the recommendations of the MDT.

Our study had several limitations. Each institution has its own unique qualities and resources that present as logistical barriers specific to that site. The results of the present study were initiated in a safety-net health center with the challenges of limited resources exacerbated by operating in the post-pandemic setting. Safety-net hospitals serve a disproportionally higher number of vulnerable patients, such as the uninsured, unhoused, and ethnic minorities regardless of their ability to pay. They often operate with limited financial resources and staffing. Although generalizability of our exact interventions may be limited to medical centers with similar patient populations and resources, this strategy is transferable to multiple settings. While we highlight specific low-cost strategies that may be implemented in institutions with similar challenges, a greater aim of this study was to demonstrate that the general methodology of the PSDA cycle offers a systematic way of implementing and scaling multiple interventions to maximize efficiency and productivity. This would provide an added benefit in settings with incentives for improved productivity and efficiency.

In addition, although relatively fewer procedures were supported by the anesthesia services, optimization of this resource was the target of our primary intervention. Another challenge is that prolonged procedures or technical complications may adversely impact EU function. To systematically adjust for no-shows, lengthy procedures, and AEs, as part of our secondary interventions, we scheduled a greater proportion of procedures in the morning. This affords greater flexibility for subsequent procedure flow throughout the day. Although this does not completely eliminate delays due to emergent cases or lengthy procedures, overall EU productivity ultimately improved in part due to this buffer for unforeseen events. Finally, observational bias due to the Hawthorne effect may have led us to overestimate improvement, which may wane when the period of observation concludes. We aim to continue monitoring operations by programming key steps of EU processes into the EMR

and meeting regularly to follow up on and recommend additional interventions.

This study also underscored several needs in the field of endoscopy operations research. In Phase 1, we determined baseline performance metrics, comparing them to values from prior studies [7, 11]. Nevertheless, terms such as "turnover time" are defined heterogeneously. Future studies will benefit from standardized metrics (quantifiable variables) of endoscopy operations according with Agency for Health Care Research and Quality (AHRQ) guidance and reference values for defined scenarios (benchmarks) [7, 18]. Future systematic work using a scientific approach to operations may be used to develop practical endoscopy operations guidelines. For example, Kaushal et al found that a ratio of 1.67 endoscopy rooms to PPU beds was inadequate and proposed a ratio of 2 to 2.5 [11]. A number of studies have demonstrated that providing more than one procedure room per physician increases efficiency if the "efficiency quotient" (actual procedure time: total time in EU) is less than 0.5 [13, 19, 20].

Conclusions

In this study, we demonstrated the use of the PDSA ramp model to improve core efficiency metrics in EUs, employing a multidisciplinary team cognizant of local factors to guide successful intervention. The ramp model employed quantitative metrics to drive policy in a patient care setting and engendered cooperation among personnel to optimize implementation of interventions. Prospective analysis confirms that this approach may also improve room throughput, overall productivity, and core efficiency metrics (i. e. first case on-time start) in an EU.

Conflict of Interest

The authors declare that they have no conflict of interest.

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