QUALITY, SAFETY AND EFFICIENCY IN PRACTICE: RISK ASSESSMENT AND STANDARDISATION OF ANESTHESIA EQUIPMENT AND SUPPLIES IN OPERATING THEATERS OF HIGH-VOLUME TERTIARY-CARE ACADEMIC MEDICAL CENTER

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Abstract

Background: Operating theatres (OTs) are valuable and costly resources that need to be appropriately designed and stocked for efficient, quality and safe patient care. We assessed the logistic inefficiency including the availability and location layout of necessary supplies across OTs of a high-volume tertiary-care academic medical center.

Methods: A blinded observer (anesthesia technologist) was allocated to 10 OTs. For each OT, the availability, quantity and time spent to locate and obtain a set of required items were recorded (baseline values). We then developed an OT mapping plan to determine the specific item/s to be stocked in specific locations, and one OT was standardized to this configuration map. A blinded observer was then allocated to this standardized OT and time spent to obtain the same set of items was again recorded. Six of our regular OTs were then standardized to the same configuration, and the time to obtain the items by a blinded observer were again recorded for each OT. T tests compared the time required to locate items in the standardized OT *vs.* regular OTs; paired t tests compared the time required in each OT *vs.* itself before and after standardization.

Results: The observer required significantly more time in each of the 10 regular OTs compared to the standardized OT. The time spent by the observer to obtain the required items significantly and considerably decreased in each of 6 OTs after their standardization, compared to the time required before their standardization.

Conclusion: This quality improvement project successfully reduced the time required to identify and locate different supplies, which impacts on the efficiency and quality of patient care. For anesthesia staff moving from one anesthetizing location to another within the institution, consistencies in location and number of anesthesia equipment and supplies create higher levels of safety and professionalism.

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Introduction

The appropriate setting up of an operating theatre with all required anesthetic equipment helps health care providers to deliver efficient service in timely manner and is crucial when managing critically sick patients, particularly those requiring life-saving procedures. The American Society of Anesthesiologists (ASA) found a high incidence of equipment-related problems among patients[1] and human errors are not infrequent than equipment failures[2]. In the UK, anesthetic equipment incidents have generally not been critically scrutinized to the extent that they should be[3]. Anesthetic equipment-related incidents (failure or unavailability) comprised 15.7% of a total of 606 incidents between 2006-2008[4]. Similarly, in Kuwait, no control mechanisms existed for the supply and inventory management domain, resulting in an uncontrolled consumption, non-moving and lots of expired and stocked items as no updated inventory was available to reflect what is stocked in every area, with the subsequent outcome that one might find no single item of the highly consumable supplies whilst finding hundreds of low utilization ones[5].

Despite that maintaining patient safety is a critical element of anesthetic practice[6], operating theatres are frequently stuffed with many types of equipment in an unorganized manner[5]. Such measures inevitably impinge directly on patient safety and quality of care. Unsurprisingly, the analysis of stock, instrument placement and devising of standardized surgical set-ups led to more efficient practice[4]. Likewise, the use of standardized, bundled surgical items facilitated the location and procurement of supplies[4].

The ASA recommends that space must be available in operating theaters to store a wide variety of disposable equipment of different sizes within easy reach of providers[7]. Such equipment includes intravenous catheters, fluid flow systems, infusion pumps, and equipment for invasive monitoring of arterial and central venous pressures[7]. They also comprise regional anesthesia equipment for neuraxial and peripheral nerve blocks, resuscitation equipment, and readily available medications. Likewise, the difficult airway cart with specialized equipment should include, but not be limited to, fiberoptic bronchoscope and emergency tracheostomy and cricothyrotomy equipment, and malignant hyperthermia treatment cart should be regularly maintained and include a range of medications[7]. Despite such recommendations, OTs were stuffed with many types of equipment left around in a disorganized fashion.

The literature reveals gaps. Research that focuses on the levels of efficiency and productivity across OTs in a systematic unified approach seems to be lacking and/or not widely reported[8]. Geographically, to the best of our knowledge, across the Eastern Mediterranean Region, there exists very scarce published research that addresses the efficiency and productivity of OTs. Particularly across the countries of the Arabian Gulf area, there are no recent data available and not a single published paper on the topic. This is despite that: 1) with longer projected life expectancy of populations, demand for surgical services and OTs continues to increase; 2) proper OT arrangement with all necessary anesthetic gear helps anesthetists to deliver timely efficient services which is key for critical procedures and patients; 3) the concept of "standardization" of services and care processes allows providers to practice in a more efficient environment; and, 4) maintaining economically viable institutions require cautious resource use.

Given these knowledge gaps, the aim of the current study was to assess the effect of standardization of amount, type, arrangement and availability of anesthesia equipment and supplies in OTs of a major tertiary care hospital, on the time consumed by anesthetists to identify and reach the desired equipment/ supplies. Using 11 identical OTs and employing the same anesthesia technologist to locate and access an identical set of given equipment/ supplies within the OTs, the specific objectives were to:

- Assess the time required by the technologist to locate and access the equipment/ supplies in each of 11 regular OTs.
- Develop a mapping plan to determine the specific item to be stocked in a given location and implement the plan to generate a reference standardized OT.
- Measure the time required by the technologist

to locate and access the equipment/ supplies in the reference standardized OT.

- Assess the extent of delay (time difference required by the technologist to locate and access the same equipment/ supplies between regular and the reference standardized OT).
- Implement the standardization across all the OTs, and assess the extent of improvement in time.

Methods

Risk assessment: defining the problem Initial Analysis: Direct Observation Of Baseline Process

At our tertiary care institution, the need for the standardization of anesthesia equipment and supplies in the OTs was raised after we observed several inconsistencies. Each of the 11 OTs had different anesthesia supply carts and cabinets, each with its own configuration and layout. In addition, the drawers and shelves were overloaded with rarely used items. Hence, the preparation for anesthesia procedure consumes long and valuable time. As our anesthesia physicians and technicians rotate between 11 OTs and 52 procedure rooms across different sections and units, thus they spend valuable time searching for anesthesia items which wastes time, increases frustration and increases the potential for errors.

Visual management strategy: potential solution/s

The 5S or visual management strategy of the Lean and Six Sigma methodologies include the use of techniques that enables a person to immediately recognize normal and abnormal states in the process. Such technique helps an organization examine the work place and identify irregularities for easy elimination of waste and improving safety[8]. The 5S components are: Sort (distinguish what is needed and what is not needed), Set in order (place everything in its place), Shine (make cleaning part of the job every day), Standardize (create policies and procedures that ensure the area stays clean and neat at all times) and finally Sustain (train workers and management to be committed to and participate in sustaining and monitoring visual management)[8].

Plan and action

We conducted an audit to recognize and verify the risk of irregularities at our OTs and to develop a mapping plan to determine the specific item to be stocked in a given location.

Before starting the audit, we standardized one reference OT according to a studied configuration map (items' location and quantity) (Table 1). Then, a blinded anesthesia technologist was allocated to the reference OT, where a list of required equipment was then presented to the technologist, and the availability, quantity and time spent by the technologist to obtain each of the required items was recorded (baseline measurement). We then compared this time required in the standardized OT to the time taken by the same observer to locate the same items in the other 10 regular OTs under examination. Then, we standardized 7 OTs similar to the reference OT (3 OTs were excluded due to limited logistics). We then conducted a second identical survey using the same principles in order to measure any improvement in the time to locate items in the 7 standardized OT before and after standardization. Time spent by the technologist to obtain each of the required items before and after standardization was recorded as mean and standard deviation. Independent t-test was used to compare quantitative variables with normal distribution before and after standardization. All statistical tests were 2-sided with a $P < 0.05$ considered statistically significant.

Results

We standardized OT3 according to the action plan, and compared it to the other 10 OTs employing an anesthesia technician blinded to the status of the OT (i.e. whether a given OT was standardized or not). Figure 1 depicts that the time spent by the anesethesia technician to locate the chosen items and supplies in the standardized OT3 (4.94 sec) ranged between 4

Anesthesia Cupboard													
Shelf 1	**Ringers Lactate** (10 bags)												
Shelf 2	**Plasma Protein 5%** (6 bottles) **Gelofusine** (2 bottles)						**Normal Saline** (8 bags)						
Shelf 3	**NGT** 18F 2Ps 16F 2PS 18F 1Ps 16F 1PS 18F 1Ps **Bile bag** (2P)		**IVAC syringes** (5P)				**Eye Protector** (5P)				**BIS** (10P)		
			IVAC extensions (10P)				**Opsite** (10P)						
			3 way TIVA set (2P)				**Wound dressing** (5 P)						
Drawer 1	**CVP Set** (5P)		**Tegaderm 7 X 8.5 cm** (5P)		**Arterial Catheter**		**Transducers**						
					Arrow 20G (10 P)		**Single set** (5P)						
	40 cm Extension line (5 P)		**10 X 12 cm** (5P)		**Vygon** (5P)		**Dual set** (1P)						
					BD art (5P)		**Micro sampler** (10P)						
Drawer 2	**Octopus 3** (2P) **Octopus 2** (2P)		**IV extensions**		**Terumo Cannula**		**IV Cannula**						
			100 cm (10P)		**G18-G24** (3 Ps each)								
			10 cm (10P)		**3 way Connector (5 Ps)**								
			IV set (10P)		**Needles**		**G14 -16** (5P)						
			Blood set (10P)		**G18** (50P) **G20-25** (30P each)		**G18-22** (10P)						
Drawer 3	**Blood set** (5P) **Inflow water cartridge** (10P)		**Soluset** (2Ps) **Haemoset** (1P)		**Nasal Airway**		**Oropharyngeal airway**						
							Ped				**Adult**		
					S7- (1p)		**S000**	5P			**S2**	4P	
							S00	5P			**S3**	4P	
					S8- (1P)		**S0**	5P			**S4**	4P	
							S1	5P					
Drawer 4	**Endotracheal tubes adults**										**Armored tubes**		
	S6	**S6.5**	**S7**		**S7.5**		**S8**		**S8.5**		**S6-8**		
	3P	3P	4P		4P		4P		3P		2P **Each**		
Drawer 5	**Endotracheal tubes Pediatric**										**Uncuffed**		
	S2.5	**S3**	**S3.5**	**S4**	**S4.5**		**S5**		**S5.5**		**S2.5-5.5**		
	2P each										2P **each**		
Drawer 6	**Laryngeal Mask**												
	S1	**S1.5**	**S2**	**S2.5**	**S3**		**S4**		**S5**				
	2P	2P	2P	2P	1P Supreme		1P Supreme		1P Supreme				
				Ambu	1P Ambu		3P Ambu		1P Ambu				

Ps: pieces.

(OT7) to 18 (OT5) times less when compared to the the time required by the same technician to locate the same items across the other non standardized OTs ($P < 0.0001$ for all comparisons).

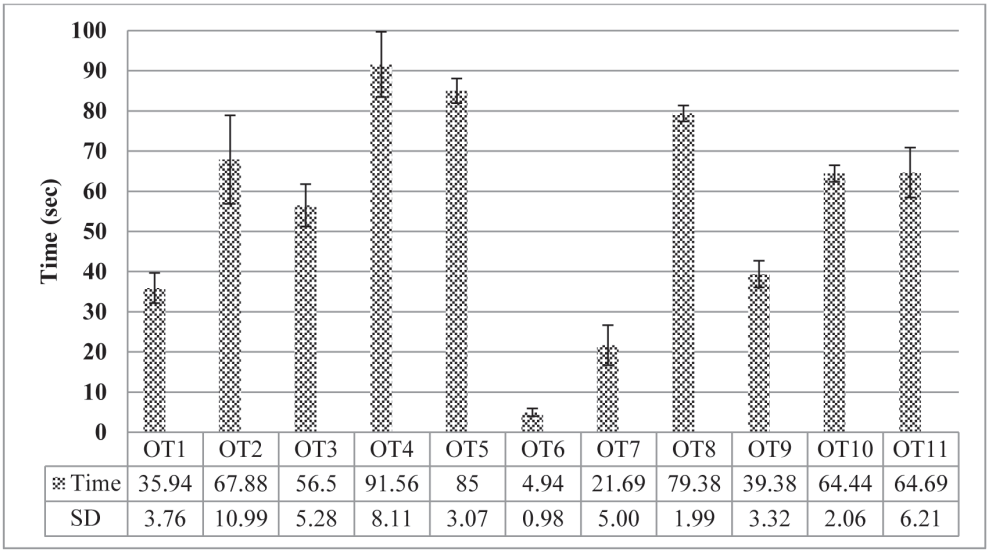
OT: operating theatre.

Figure 2 shows that across the seven standardized OTs, the decrease in time spent by same technician to locate the items varied from 17.94 sec (OT7) to 75.19 sec (OT 8). This decrease in time was larger across 4 OTs, and less across another 2 OTs ($P < 0.0001$ for all comparisons).

Discussion

Hamad General Hospital is an 800- bed major tertiary care hospital in Doha, Qatar, with 18,600 surgeries undertaken in 2016. OTs are a hospital's costly resource[9], and time is the most expensive factor in the OT[10]. A number of OT processes can limit productivity, and authors have reported variables and processes that contribute to OR inefficiencies[11-14], where inventory management procedures of controlling and stocking medicines, general medical supplies and instruments

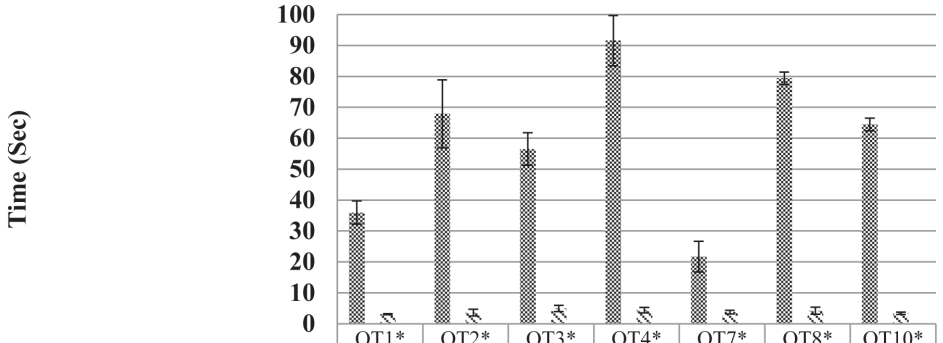
Fig. 1
Time to locate items in the standardized OT and 10 non-standardized OTs



	OT1	OT2	OT3	OT4	OT5	OT6	OT7	OT8	OT9	OT10	OT11
Time	35.94	67.88	56.5	91.56	85	4.94	21.69	79.38	39.38	64.44	64.69
SD	3.76	10.99	5.28	8.11	3.07	0.98	5.00	1.99	3.32	2.06	6.21

OT: operating theatre.

Fig. 2
Time to locate items in 7 OTs before and after standardization.



	OT1*	OT2*	OT3*	OT4*	OT7*	OT8*	OT10*
Time before Standardization, Mean	35.94	67.88	56.5	91.56	21.69	79.38	64.44
SD	3.76	10.99	5.28	8.11	5.00	1.99	2.06
Time after Standardization, Mean	3.06	3.56	4.94	4.38	3.75	4.19	3.38
SD	0.16	1.10	1.00	0.91	0.57	1.13	0.36

OT3 is the Model OR; SD: standard deviation; * indicates statistically significant difference in the time before and after standardization

were critical factors. Hence, ensuring that this resource is well designed, appropriately and efficiently utilized is critical to the quality of patient care and financial productivity[9].

Numerous factors constrain OT productivity and efficiency, including infrastructure (e.g. available storage areas). The manufacturing industry has managed their processes to maximize efficiency, enhance productivity, decrease personnel costs, reduce waste, and increase financial performance[15]. Recently, the focus has shifted from efficiencies gained at the production level to efficiencies gained across the entire organization. Lean and Six Sigma are 2 methodologies used at the work unit and organizational level in operating and recovery room settings[15,16]. These methodologies increase efficiency by reducing wasteful steps that do not add value to the overall process, product or service end user[17]. Such methodologies continually reduce waste, reduce process variation, and improve workflow to efficiently produce a product/service perceived to be of high value to those who use it[11] through the rigorous process metrics collection and statistical analysis[18]. In line with others[19], we employed the Lean system to improve OT efficiency and quality of the service and to reduce waste and unproductive times, in order to generate more positive outcomes.

In the USA, researchers used a Six Sigma process to decrease turnaround time between general surgery cases[20]. Our findings of improved time utilization (from 17.94 sec to 75.19 sec) in accordance with their results. Additionally they demonstrated that a decrease in turnaround time resulted in increased surgical throughput with a resulting positive financial return[20]. Our findings again support such savings, where the average time saved by standardizing our OTs for anesthesia equipment was 69.5 second per patient, which directly translates to an average of 3,198 hours per year for the annual case load (18,600 surgeries) we encounter in the one hospital we investigated. Given that Qatar has seven major hospitals, the financial and time resources that could be saved are substantial. Indeed, the time lost in searching for anesthetic materials and locating various pieces of equipment delays and prolongs anesthesia time (time stamp from the time a patient is attached to OTs monitor to endotracheal extubation) that decreases OT efficiency.

Such time, money and costs savings need to be considered, particularly that one hour of OT time costs approximately $500, exclusive of supply and personnel costs[10]. OT quality improvement processes akin to the one described in this study can lead to cost savings based on higher efficiency, with subsequent decreases in “wheels in” to “wheels out” time, as well as the time where the patient is in the OT to end of induction[21]. Given that OT time utilization in a cancer hospital showed that anesthesia-related processes contributed to 17% of total OT time, with turnover time between cases accounting for 4%[22], the standardization of quantity, location and type of supplies and equipment as decribed in this study are critical components. Others confirm such savings, where the time spent doing procedures comprised only about 40% of the total operational time in a burn OT, and besides the procedure itself, the second and third largest components of an operation were turnover and preparation time, respectively[21].

Time saving should not impact patient safety[10], and is consequently expected to translate to enhanced patient safety. In agreement with our findings, others used sigma and lean processes to address deficiencies in pediatrics anesthesia supply chain and redesign the anesthesia cart, and improved their metrics and sustained it for one year[23], and likewise, research in Italy confirmed that implementing a lean system may enhance efficiency and service quality to decrease waste and unproductive times that would inevitably generate a more positive outcomes[19].

Conclusion

The presented quality improvement project was successful in reducing the time taken to identify different supplies, which provided incentives for the stakeholders to move forward and a faster pace. From the perspective of an anesthesia staff moving from one anesthetizing location to another within the corporate, the consistencies in the anesthesia equipment and supplies locations creates a significantly higher level of safety and professionalism.

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