J Med Syst (2014) 38:11
DOI 10.1007/s10916-014-0011-7

RESEARCH ARTICLE

Variability of Subspecialty-Specific Anesthesia-Controlled Times at Two Academic Institutions

Bhavani Shankar Kodali · K. Dennie Kim · Hugh Flanagan · Jesse M. Ehrenfeld · Richard D. Urman

Received: 1 December 2013 / Accepted: 10 January 2014 / Published online: 28 January 2014

Abstract Realistic scheduling of operating room cases decreases costs, optimizes utilization and improves staff and patient satisfaction. Currently limited data exists to establish anesthesia-controlled time benchmarks based on specific subspecialty service. In this multicenter retrospective analysis of cases performed during a 53 month period at two large multispecialty academic institutions, data were retrieved from the perioperative information systems at each center. Both induction and emergence times were calculated. We then determined mean and median anesthesia controlled times based on each subspecialty service and compared them to previously published anesthesia-controlled time data. We obtained data on 104,184 cases at hospital A, and 122,560 cases at Hospital B. For all specialties at hospital A and hospital B, median induction time was 16.0 min and 17.0 min, emergence time was 14.0 and 8.0 min, and total anesthesia controlled time was 31.0 min and 27.0 min respectively. There was considerable variability among different surgical specialties deviating from the previously established 30 min benchmark. Subspecialties with lower total anesthesia controlled times in both centers were pain, general surgery, gynecology, plastic surgery and urology. Subspecialties with higher total anesthesia controlled times in both centers included cardiac surgery, neurosurgery, transplant and vascular. Cardiac surgery had the highest total time of 60 min and 50 min at Hospital A and B respectively. Individual specialty-specific anesthesia controlled times should be used for case scheduling and to benchmark anesthesia performance.

Keywords Anesthesia controlled time · OR efficiency · OR management · OR benchmarks

B. S. Kodali · K. D. Kim · H. Flanagan · R. D. Urman
Harvard Medical School/Brigham and Women's Hospital, Boston, MA, USA

J. M. Ehrenfeld
Vanderbilt University Medical Center, Nashville, TN, USA

R. D. Urman (✉)
Department of Anesthesia, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA
e-mail: urmanr@gmail.com

Introduction

In an era of decreasing reimbursement and aggressive cost-cutting by hospitals, running an efficient and profitable operating room (OR) suite has become a significant priority for both academic and non-academic institutions [1–3]. Realistic scheduling of OR cases, including accurate prediction of anesthesia-controlled time (ACT), surgical time, and turnover time (TOT) helps improve staff and patient satisfaction, decrease costs and minimize under- or overutilization of the OR [4, 5]. Several benchmarks such as ACT, surgical control time, and TOT are used to gauge the operational efficiency of operating rooms. However, little work has been done to establish ACT benchmarks for heterogeneous tertiary care academic institutions, especially ACT benchmarks for each major surgical subspecialty service.

Although there are no standards for ACT, most hospitals use 30 min as a benchmark and arbitrarily divided that time interval into 15 min for completion of induction (ACT 1) and 15 min for anesthesia emergence (ACT 2) that occurs after the procedure is completed, but before the patient is ready to be transferred to post-anesthesia recovery [6]. However, in clinical practice there is a substantial variation in ACT among surgical subspecialties and between ACT 1 and ACT 2. Additionally, there is no precise benchmark data available for ACT's as a reference for each subspecialty. Previous studies have examined ways to predict anesthesia induction times [7, 8], reasons for anesthesia-related delays [8], predictors of anesthetic inductions times taking into consideration patient, anesthetic and procedure characteristics [9], as well as ways to decrease ACTs [10].

The purpose of this retrospective study is to determine actual ACTs for each surgical service at two large academic institutions that can be used as benchmarks to improve planning of OR schedule based on the subspecialty.

Materials and methods

Case selection and data collection

This two center study was conducted at Brigham and Women's Hospital (a 793 bed adult tertiary referral center) and Vanderbilt University Medical Center (a 1,023 bed tertiary referral center), using hospital quality data to obtain ACTs during a 53-month period from October 2008 to February 2013. Data were analyzed for each surgical division, and mean and median ACT values were calculated. In our analysis we included 16 surgical subspecialties that performed at least 100 cases over the study period.

We used the ACT definition as established by the American Association of Clinical Directors [11]. The Induction time or ACT 1 was defined as the period starting when the patient entered an OR to when the airway was secured and the patient was turned over to the surgical team. Emergence time or ACT 2 was defined as the time starting when the surgical dressing was completed to when the patient was ready to be transferred. ACT is the sum of ACT 1 and ACT 2.

ACT 1 and ACT 2 were calculated for each unique surgical case on record, using a subset of timestamps that are routinely documented by the operating room staff throughout the duration of a surgical procedure. Relevant timestamps at the two hospitals were "Patient Into OR," "Induction Complete," "Surgery End," and "Ready to Transfer." Timestamps are generally entered synchronously with the referenced event by a single keystroke that automatically populates the current time. However, timestamps can also be manually entered, thus introducing some human error and variability. This is not unique to the clinical systems in use at the two study hospitals, but is rather a limitation in many electronic clinical systems for intraoperative documentation.

Statistical analysis

ACT data was calculated using actual OR time points for unique surgical cases. The time points used were electronically documented intraoperatively by the operating room staff assigned to each case. For mean and median ACT figures and ACT distributions, data analysis, including calculations of means, medians and standard deviations, was performed using SAS (version 9.2, Cary NC) and Microsoft Excel software (version 2011). Cases were excluded from the analysis if (a) one or more time stamps necessary for either ACT 1 or ACT 2 calculations were missing or (b) data was anachronistic, or (c) data was not realistic.

Results

We obtained complete data on a total of 104,184 cases at Hospital A and 122,560 at Hospital B. Mean and median ACT values are shown in Tables 1 and 2 and a list of all subspecialties with corresponding median ACT times is shown as a bar graph in Fig. 1.

Variability between surgical subspecialties

For all specialties combined, the median induction time (ACT 1) was 16.0 min at Hospital A and 17.0 min at Hospital B. Anesthesia emergence time (ACT 2) was 14.0 min at Hospital A and 8.0 min at Hospital B. The median total ACT was 31.0 min at Hospital A and 27.0 min at Hospital B (Tables 1, 2 and Fig. 1). There was considerable variability among different surgical specialties. Median values for ACT 1, ACT 2, and total ACT were similar to mean values in nearly every case. Using a 30 min total ACT (ACT 1+ACT2) benchmark [6], subspecialties with relatively low total ACT values were the following: pain, burn, general surgery, gynecology, orthopedics, oncology, plastic surgery, and urology. Subspecialties with lower total anesthesia controlled times in both centers were pain, general surgery, gynecology, plastic surgery and urology. Subspecialties with higher total anesthesia controlled times in both centers included cardiac surgery, neurosurgery, transplant and vascular. At both centers, the top service with the highest total median ACT values was cardiac surgery with values of 60.0 min and 48 min at Hospital A and B respectively.

Variability within surgical subspecialties

In addition to the variability that we observed between surgical subspecialties, we examined the variability within each subspecialty at Hospital A as shown in Table 3. We grouped total ACT time into 10-min intervals and calculated the distribution of cases within each. No more than 38 % of cases within a single service correlated to a single interval, and, for most services, total ACT for the majority of cases would span a 30 to 40-min range. For instance, in Neurosurgery (n= 4,545) about 32 % of cases had a total ACT of 0–30 min, another 40 % were between 31–50 min, and 28 % were longer than 50 min (Fig. 2).

Table 1 Anesthesia controlled times by surgical specialty Hospital A, Oct 2008–Feb 2013

Service		N	ACT1				ACT2				Total ACT (ACT1+ACT2)			
			Sum	Median	Mean	Standard deviation	Sum	Median	Mean	Standard deviation	Sum	Median	Mean	Standard deviation
ANE	Pain service	610	10,827	17.00	17.75	7.60	9,611	14.00	15.76	8.91	20,438	32.00	33.50	12.20
BTS	Burn trauma	3,538	61,402	15.00	17.36	11.14	59,107	14.00	16.71	16.40	120,509	30.00	34.06	20.93
CAR	Cardiology	758	21,840	26.00	28.81	13.19	13,018	15.00	17.17	12.49	34,858	43.00	45.99	19.13
CSS	Cardiac surgery	5,892	275,402	45.00	46.74	18.48	100,639	14.00	17.08	17.23	376,041	60.00	63.82	25.63
DEN	Dentistry	143	3,448	21.00	24.11	10.80	4,634	21.00	32.41	118.39	8,082	45.00	56.52	118.74
GGI	General & GI surgery	13,366	219,252	15.00	16.40	8.10	205,419	13.00	15.37	9.87	424,671	29.00	31.77	13.85
GYN	Gynecology	15,624	246,152	15.00	15.75	6.73	228,719	13.00	14.64	8.26	474,871	29.00	30.39	11.29
NSU	Neurosurgery	6,108	168,983	24.00	27.67	17.86	144,157	20.00	23.60	15.07	313,140	46.00	51.27	24.92
ORT	Orthopedics	15,358	310,999	17.00	20.25	12.76	206,161	11.00	13.42	10.26	517,160	30.00	33.67	17.82
OSS	Surgical oncology	6,758	121,607	15.00	17.99	10.54	99,843	13.00	14.77	10.15	221,450	29.00	32.77	16.37
OTO	Otorhinolaryngology	4,657	82,440	16.00	17.70	8.06	82,826	16.00	17.79	10.68	165,266	33.00	35.49	14.80
PLA	Plastic surgery	6,618	108,857	15.00	16.45	8.10	98,872	13.00	14.94	10.17	207,729	29.00	31.39	14.20
RTR	Transplant surgery	735	21,199	22.00	28.84	19.47	13,184	15.00	17.94	12.17	34,383	40.00	46.78	24.56
THO	Thoracic surgery	11,799	195,531	14.00	16.57	11.01	219,159	15.00	18.57	13.63	414,690	31.00	35.15	18.84
URO	Urology	8,103	125,934	14.00	15.54	8.06	109,891	12.00	13.56	8.71	235,825	27.00	29.10	12.91
VAS	Vascular surgery	3,888	89,629	19.00	23.05	18.58	65,923	15.00	16.96	12.11	155,552	35.00	40.01	23.60
All cases		104,184	2,067,733	16.00	19.85	13.64	1,665,140	14.00	15.98	12.53	3,732,873	31.00	35.83	19.86

Table 2 Anesthesia-controlled times—Hospital B October 2008–February 2013

	Count of ACT 1	Median ACT 1	Mean of ACT 1	StdDev of ACT 1	Median ACT 2	mean of ACT 2	StdDev of ACT 2	Median ACT1 +ACT 2	Mean of ACT1 +ACT 2	StdDev of ACT1+ACT 2
Anesthesia (Pain)	115	13.00	14.63	9.91	7.00	7.94	5.75	20.00	22.57	12.00
Burn	1,949	22.00	24.31	13.80	10.00	11.62	8.45	33.00	35.93	17.09
Cardiac	4,241	37.00	38.00	16.70	10.00	11.89	11.23	48.00	49.89	20.31
Dentistry	2,548	18.00	20.29	11.95	10.00	11.39	7.64	30.00	31.69	15.22
General & GI surgery	19,671	15.00	17.09	11.19	9.00	10.57	9.10	25.00	27.66	15.35
Gynecology	8,393	13.00	15.35	8.98	6.00	7.13	5.64	20.00	22.48	11.25
Neurosurgery	10,863	25.00	28.72	18.91	11.00	13.21	9.82	37.00	41.93	23.28
Orthopedic	22,544	19.00	22.49	15.10	8.00	9.74	30.21	28.00	32.22	34.28
Oncology	8,344	15.00	17.97	12.13	7.00	8.41	6.58	23.00	26.38	15.29
Ophthalmology	4,708	11.00	12.32	7.01	5.00	6.60	5.72	17.00	18.92	10.55
Otorhinolarnygology	8,907	16.00	19.24	21.76	11.00	12.26	7.91	28.00	31.50	23.58
Plastic surgery	6,230	17.00	19.69	11.89	8.00	9.82	7.02	27.00	29.51	14.98
Thoracic	3,103	24.00	27.74	19.42	11.00	13.93	12.04	38.00	41.67	23.69
Transplant	1,627	30.00	33.38	20.49	11.00	14.65	16.45	44.00	48.04	26.33
Urology surgery	14,756	14.00	16.45	9.35	8.00	8.93	6.00	23.00	25.38	11.68
Vascular surgery	4,561	17.00	21.56	15.71	7.00	11.21	109.80	26.00	32.77	111.08
Grand total	122,560	17.00	20.64	15.27	8.00	10.24	25.95	27.00	30.88	30.88

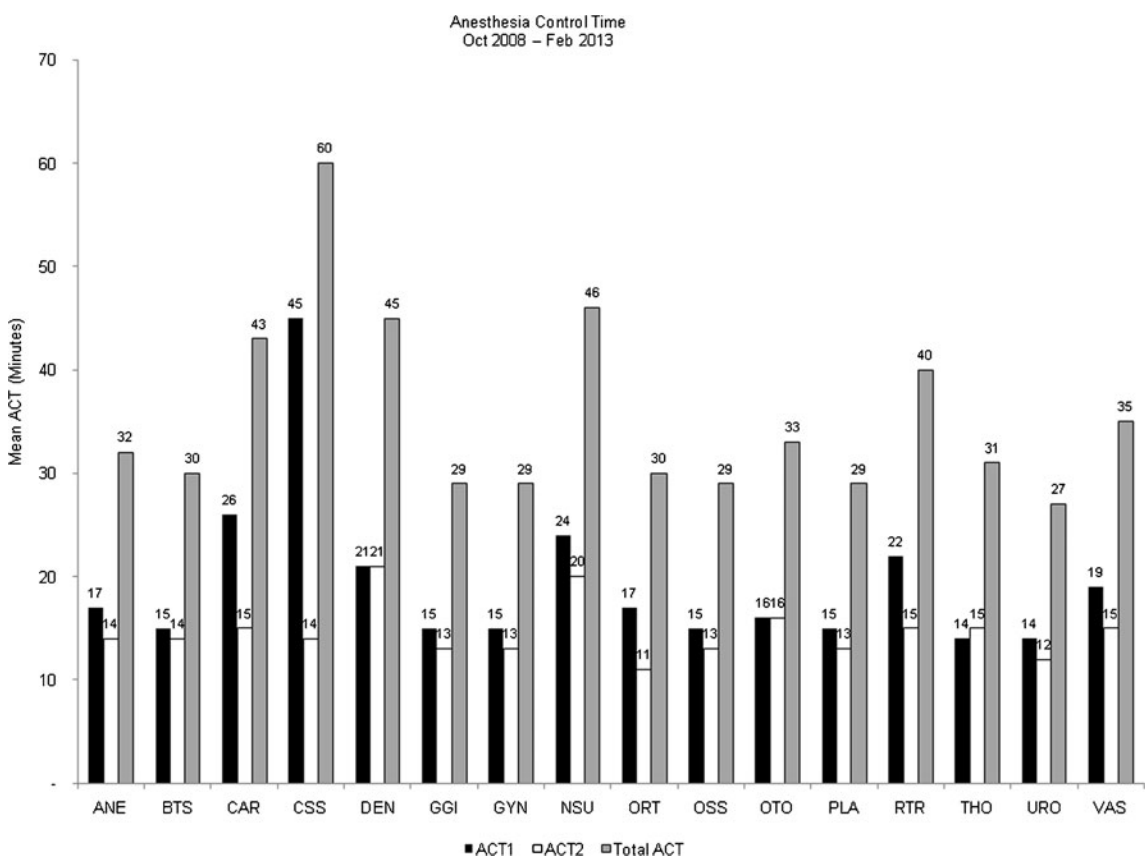

Fig. 1 Median anesthesia-controlled times Hospital A (October 2008–February 2013)

Table 3 Total ACT distribution by surgical specialty Hospital A, Oct 2009–Sep 2012

Service		Total ACT (ACT1+ACT2) Range (Min.)										
		N	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	>90
ANE	Pain service	434	9 %	26 %	34 %	20 %	6 %	3 %	1 %	0 %	0 %	0 %
BTS	Burn trauma	3,110	14 %	28 %	26 %	16 %	7 %	3 %	2 %	1 %	2 %	1 %
CAR	Cardiology	4,216	1 %	2 %	6 %	16 %	23 %	21 %	13 %	8 %	3 %	6 %
CSS	Cardiac surgery	537	1 %	12 %	23 %	28 %	18 %	7 %	5 %	3 %	1 %	2 %
DEN	Dentistry	97	2 %	13 %	21 %	27 %	18 %	12 %	5 %	2 %	0 %	0 %
GGI	General & GI surgery	9,319	8 %	30 %	37 %	16 %	5 %	2 %	1 %	0 %	1 %	1 %
GYN	Gynecology	11,106	10 %	33 %	36 %	15 %	4 %	1 %	0 %	0 %	1 %	0 %
NSU	Neurosurgery	4,545	2 %	9 %	21 %	23 %	17 %	10 %	7 %	4 %	2 %	4 %
ORT	Orthopedics	11,398	11 %	27 %	29 %	17 %	8 %	4 %	2 %	1 %	1 %	1 %
OSS	Surgical oncology	2,826	11 %	31 %	30 %	14 %	6 %	3 %	1 %	1 %	1 %	1 %
OTO	Otorhinolaryngology	4,865	6 %	23 %	34 %	23 %	8 %	3 %	1 %	1 %	1 %	0 %
PLA	Plastic surgery	557	12 %	30 %	32 %	16 %	5 %	2 %	1 %	0 %	1 %	0 %
RTR	Transplant surgery	5,329	3 %	17 %	23 %	18 %	12 %	6 %	8 %	3 %	3 %	6 %
THO	Thoracic surgery	8,788	11 %	30 %	28 %	15 %	7 %	4 %	2 %	1 %	1 %	1 %
URO	Urology	5,790	14 %	37 %	30 %	12 %	3 %	1 %	1 %	0 %	1 %	0 %
VAS	Vascular surgery	3,027	8 %	21 %	29 %	18 %	10 %	6 %	3 %	2 %	2 %	2 %
All cases		76,042	9 %	27 %	30 %	16 %	8 %	4 %	2 %	1 %	1 %	1 %

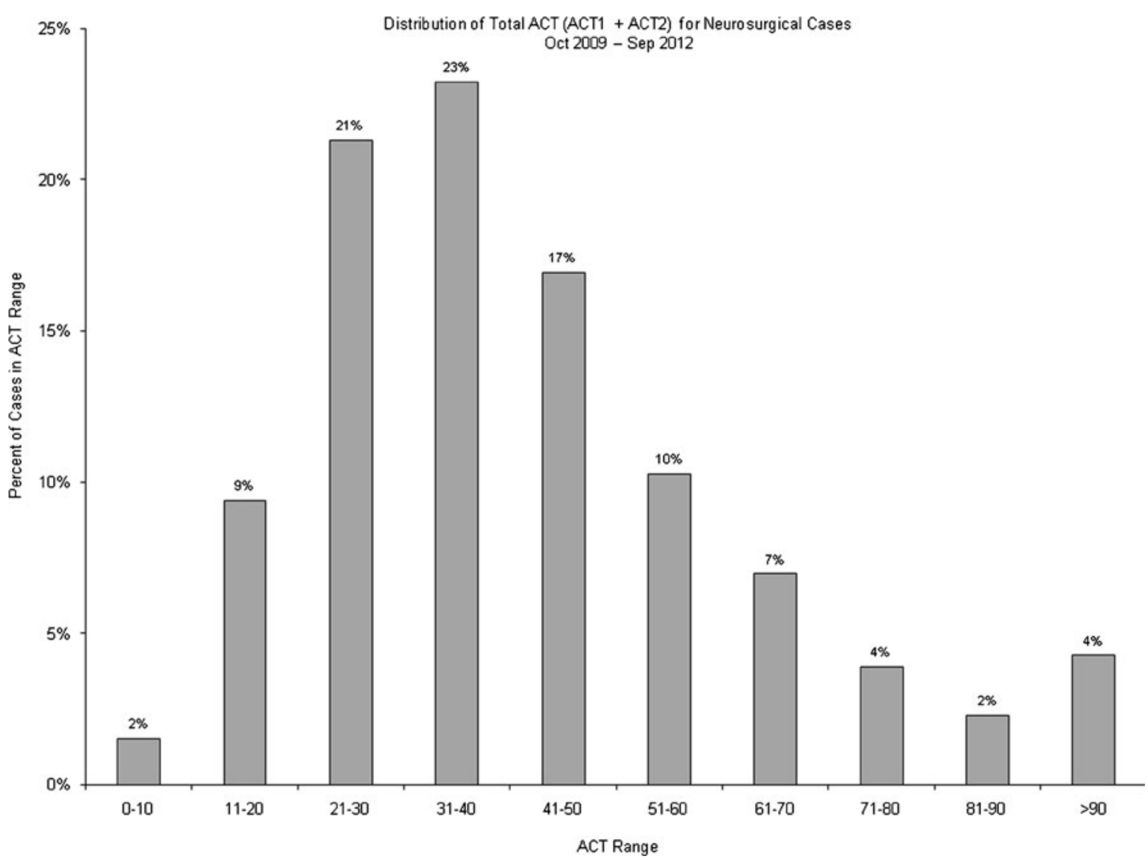

Fig. 2 Variability of total ACT within neurosurgery, Hospital A

Discussion

The results of our study show that there is significant ACT variability among different surgical subspecialties at two academic tertiary care centers. Although benchmarks have been reported for first case start times, turnover times and surgical service-specific times [12] as well as strategies for OR utilization and scheduling [5, 13–16], currently there is no clear ACT benchmark for such heterogeneous case mix; using our data allows for more realistic estimate of case duration for OR scheduling purposes.

The needs of each surgical division varied considerably, resulting in different ACTs 1 and 2. Thus, it may be prudent to use individual specialty-specific times as reference to gauge the efficiency process of OR utilization. Furthermore, division-specific ACTs offer an arena for divisional leaders to analyze factors responsible for each ACT and provide an opportunity to implement customized measures to increase efficiency. Thus, using benchmarks of ACTs obtained from institutions performing few specific specialized surgeries may not apply to heterogeneous teaching institutions.

Zafar et al. [2] attempted to evaluate and standardize the ACT 1 time for different anesthetic procedures, and also to identify the causes of delays. They took into consideration patient's conditions as defined by the American Society of Anesthesiologist Physical Status (ASA PS) Classification and need for invasive procedures during induction. The authors set an ACT 1 benchmark of 15 min for ASA PS I and II patients, 30 min for ASA PS III and IV patients, 20 min for spinal and 30 min for epidural. Major reasons for induction delays exceeding their set benchmarks included teaching of medical students and residents, line placement and airway techniques.

At both centers the high median ACT time for cardiac cases is likely a result of the need for central venous line (CVL) placement. Neither center involved in this study utilizes a parallel process (i.e. an induction room) to decrease start time for subsequent cases. Hospital A does have a "line room" in the operating suite for preoperative placement of arterial and central lines in cardiac surgery patients. Similar to the situation reported elsewhere in literature [6], this resource is not well utilized because often the same anesthesia team doing the first case is unable to staff / manage the subsequent case's line placement while another case is ongoing.

Only one previously published study presented ACT data based on the type of anesthesia service, although the reported data were based on relatively small number of cases compared to our study [6]. Table 4 compares previously published data with sample data from the two hospitals in our study. As was previously noted, there appears to be a great degree of variability among services at all three centers.

Since some of our specialty-specific times are longer than those reported elsewhere, it can be explained by differences in anesthesiologist work flow after the patient is brought into the operating room, such as the use of the recently instituted use of World Health Organization's surgical safety checklists [17, 18] and evolving central and arterial line placement techniques. Also we speculate that there may be differences in anesthesia team composition causing prolonged ACT1 and ACT2, such as presence of junior resident trainees, medical students, and attending staff covering two operating rooms with one trainee in each room. In fact, one previous study showed that at least in the fast-paced ambulatory environment, anesthesiologists working with trainees had significantly longer induction, emergence, and total anesthesia-controlled time compared to the anesthesiologists working alone [19]. Another study showed a relatively small effect of resident teaching on ACT 1 values [20]. Although there is evidence to the contrary [21, 22], ACTs may be adversely affected by influx of new residents in July and August [23]. Finally, each institution has specific protocols dictating where central or arterial line should be placed and also whether these lines are placed outside of the OR or after the patient is already brought into the OR. This can affect our comparison of ACTs for more complicated surgeries such as transplantation, cardiothoracic and neurological surgery.

Table 4 Comparison of ACT1+ACT2 times at the two institutions

	Overdyk et al. [6]	Hospital A	Hospital B	Hospital A difference	Hospital B difference
Vascular	36	40	33	4	−3
ENT	30	35	31	5	1
Trans	27	47	48	20	21
Ortho	33	34	32	1	−1
Gen	31	32	24	1	−7
Gyn	29	30	22	1	−7
Neuro	34	51	42	17	8
Ped	32				
CT	47	63	46	16	−1
Urol	35	29	25	−6	−10
Plast	20	31	30	11	10
Average	32	39.2	33.4	7.2	1.1

Another factor that may influence ACT times are related to the current infection control measures being enforced for CVL placement. We now place most CVLs in the OR after induction with full body drape and under ultrasound guidance [24]. The current guidelines of our institution require the US recording of various steps of line placement. The approximate time of CVL placement is about 22–25 min. It is possible that this time can be decreased by measures such as parallel processing of central lines setup and line placement prior to entering the OR [25]. Invasive lines placed for many vascular, neurosurgical and solid organ transplant cases also require additional induction time allotment. In orthopedic cases, we routinely perform peripheral nerve blocks preoperatively in the induction area which is known to reduce ACT [26].

Neurosurgical cases showed significantly higher emergence time, probably due to the nature of the patients and procedures leading to delayed recovery. Finally, although low in volume, the dentistry service routinely presents challenges associated with developmentally delayed patients leading to both induction and emergence delays.

Lessons learned and future directions

Based on the data, at one of the two hospitals operating room first case on time starts (FCOTS) have been changed to reflect actual ACT1 times rather than 20 min bench mark in cardiac, neurosurgical and dental subspecialties to be closer to reality rather than expectations that cannot be met. Subspecialty-dependent ACT times have also been added to booking schedule to gauge realistic duration of the cases to make prior nursing and anesthesia staffing coverage for day. We have not created provider-specific ACT1 and ACT2 times as the surgeons have done for "surgical controlled time." The realistic booking durations are also helpful during the weekend work flows in the OR to staff adequately and realistically.

There are added benefits of realistic ACTs in scheduling cases that have shorter ACT times. As for example, the laparoscopic surgery in ASA 1 patients, the ACT 1 and 2 times were 12 and 10 min respectively. These realistic times can benefit overall scheduling to avoid gaps between the OR case schedules due to delayed arrival of patients if 30 min benchmark is used. In order to achieve operating suite schedule predictability, our final goal is to attain a realistic schedule by implementing surgeon and procedure-specific surgical duration along with its own anesthesia control times. In fact, one recent study found that specific characteristics of each case, such as the patient's body mass index, anesthesia type and procedure type were independent predictors of anesthesia induction time [9].

Finally, additional strategies for improving anesthesia-controlled time include having an anesthesia technician expedite ACT1 by completing the necessary set up of equipment and medications, especially for anesthesia staff working alone. In addition, OR assistants can be trained to perform at least some of the roles of anesthesia technicians so that they can continue to expedite OR cases rather than just bring the patient into the OR and then leave the room. This is consistent with the so-called concept of "OR worker of the future with multiple skills". This includes having the anesthesia technician apply monitors, a pharmacy technician deliver drugs to the operating room, and an OR assistant bring the patient into the operating room.

Study limitations

There are several limitations of our current study. We did not examine the types of procedures within each service to get ACT for each type of procedure within the service. We also did not categorize the induction and emergence times based on patient ASA PS. Though ASA PS may play a role in guiding requirements for line placements, there are other factors that guide the requirement of line placements for monitoring or clinical care based on the diagnosis and proposed surgery rather than ASA PS alone. Moreover, some of the ASA 3 or 4 status patients coming from ICU have lines placed and on ventilators where the ACT 1 time can be paradoxically short.

Conclusion

This is the largest study to date that aims to establish benchmarks for ACTs using data from two large tertiary care centers. Although one can use 30 min ACT as a measure of anesthesia efficiency, this time may vary for each surgical specialty. Individual specialty-specific anesthesia controlled times should be used in judging the individual anesthesia specialty performance. Additional time for CVL placement should be added to ACT 1 wherever central lines are needed. Furthermore, if central lines are being placed for surgical reasons, it is a philosophical issue whether the central line placement duration should be included in ACT, or surgical control time.

Financial Support None.

Meetings at Which Work has Been Previously Presented None.

References

1. Dexter, F. E. R., Bayman, E. O., and Ledolter, J., Estimating surgical case durations and making comparisons among facilities: Identifying facilities with lower anesthesia professional fees. *Anesth. Analg.* 116(5):1103–1115, 2013.
2. Dexter, F., Ledolter, J., Tiwari, V., and Epstein, R. H., Value of a scheduled duration quantified in terms of equivalent numbers of historical cases. *Anesth. Analg.* 117(1):205–210, 2013.
3. Harders, M., Malangoni, M. A., Weight, S., and Sidhu, T., Improving operating room efficiency through process redesign. *Surgery* 140(4): 509–514, 2006. discussion 14–6.
4. Eijkemans, M. J., van Houdenhoven, M., Nguyen, T., Boersma, E., Steyerberg, E. W., and Kazemier, G., Predicting the unpredictable: a new prediction model for operating room times using individual characteristics and the surgeon's estimate. *Anesthesiology* 112(1): 41–49, 2010.
5. Strum, D. P. V. L., and May, J. H., Surgical subspecialty block utilization and capacity planning: A minimal cost analysis model. *Anesthesiology* 90(4):1176–1185, 1999.
6. Overdyk, F. J., Harvey, S. C., Fishman, R. L., and Shippey, F., Successful strategies for improving operating room efficiency at academic institutions. *Anesth. Analg.* 86(4):896–906, 1998.

7. Ehrenwerth, J., Escobar, A., Davis, E. A., Watrous, G. A., Fisch, G. S., Kain, Z. N., et al., Can the attending anesthesiologist accurately predict the duration of anesthesia induction? *Anesth. Analg.* 103(4): 938–940, 2006.
8. Zafar, S. U., Khan, F. A., and Khan, M., Standardization of anaesthesia ready time and reasons of delay in induction of anaesthesia. *J. Pak. Med. Assoc.* 56(3):112–115, 2006.
9. Kougias, P., Tiwari, V., Barshes, N. R., Bechara, C. F., Lowery, B., Pisimisis, G., et al., Modeling anesthetic times. Predictors and implications for short-term outcomes. *J. Surg. Res.* 180(1):1–7, 2013.
10. Dexter, F., Coffin, S., and Tinker, J. H., Decreases in anesthesia-controlled time cannot permit one additional surgical operation to be reliably scheduled during the workday. *Anesth. Analg.* 81(6):1263–1268, 1995.
11. Glossary of times used for scheduling and monitoring of diagnostic and therapeutic procedures. *AORN J.* 66(4):601–606, 1997.
12. Mazzei, W. J., Operating room start times and turnover times in a university hospital. *J. Clin. Anesth.* 6(5):405–408, 1994.
13. Donham, R. T., Defining measurable OR-PR scheduling, efficiency, and utilization data elements: The Association of Anesthesia Clinical Directors procedural times glossary. *Int. Anesthesiol. Clin.* 36(1):15–29, 1998.
14. Dufek, S., Gaucher, E., Gialanella, J., Kratochwill, E., Learned, D., Sonda, P., et al., The total quality process applied to the operating rooms and other clinical processes. *Surgery* 113(3):255–259, 1993.
15. Kanich, D. G., and Byrd, J. R., How to increase efficiency in the operating room. *Surg Clin N Am* 76(1):161–173, 1996.
16. Wright, I. H., Kooperberg, C., Bonar, B. A., and Bashein, G., Statistical modeling to predict elective surgery time. Comparison with a computer scheduling system and surgeon-provided estimates. *Anesthesiology* 85(6):1235–1245, 1996.
17. Kwok, A. C., Funk, L. M., Baltaga, R., Lipsitz, S. R., Merry, A. F., Dziekan, G., et al., Implementation of the World Health Organization surgical safety checklist, including introduction of pulse oximetry, in a resource-limited setting. *Ann. Surg.* 257(4):633–639, 2013.
18. Haynes, A. B., Weiser, T. G., Berry, W. R., Lipsitz, S. R., Breizat, A. H., Dellinger, E. P., et al., A surgical safety checklist to reduce morbidity and mortality in a global population. *N. Engl. J. Med.* 360(5):491–499, 2009.
19. Urman, R. D., Sarin, P., Mitani, A., Philip, B., and Eappen, S., Presence of anesthesia resident trainees in day surgery unit has mixed effects on operating room efficiency measures. *Ochsner J* 12(1):25–29, 2012.
20. Davis, E. A., Escobar, A., Ehrenwerth, J., Watrous, G. A., Fisch, G. S., Kain, Z. N., et al., Resident teaching versus the operating room schedule: An independent observer-based study of 1558 cases. *Anesth. Analg.* 103(4):932–937, 2006.
21. Eappen, S., Flanagan, H., and Bhattacharyya, N., Introduction of anesthesia resident trainees to the operating room does not lead to changes in anesthesia-controlled times for efficiency measures. *Anesthesiology* 101(5):1210–1214, 2004.
22. Broussard, D. M., and Couch, M. C., Anesthesia preparation time is not affected by the experience level of the resident involved during his/her first month of adult cardiac surgery. *J. Cardiothorac. Vasc. Anesth.* 25(5):766–769, 2011.
23. Unpublished Data. Department of Anesthesiology, *Perioperative and Pain Medicine. Brigham and Women's Hospital*: Boston MA.
24. Raad, I. I., Hohn, D. C., Gilbreath, B. J., Suleiman, N., Hill, L. A., Bruso, P. A., et al., Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect. Control Hosp. Epidemiol.* 15(4 Pt 1):231–238, 1994.
25. Overby, D. W., Kohn, G. P., Colton, K. J., Stavas, J. M., Dixon, R. G., Passannante, A., et al., Central venous line placement prior to gastric bypass improves operating room efficiency. *ISRN Surg.* 2012: 816871, 2012.
26. Mariano, E. R., Chu, L. F., Peinado, C. R., and Mazzei, W. J., Anesthesia-controlled time and turnover time for ambulatory upper extremity surgery performed with regional versus general anesthesia. *J. Clin. Anesth.* 21(4):253–257, 2009.