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IMPLEMENTATION SCIENCE & OPERATIONS MANAGEMENT

Benchmarking of Anesthesia and Surgical Control Times by Current Procedural Terminology (CPT®) Codes

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Abstract

Over half of hospital revenue results from perioperative patient care, thus emphasizing the importance of efficient resource utilization within a hospital's suite of operating rooms (ORs). Predicting surgical case duration, including Anesthesia-controlled time (ACT) and Surgical-controlled time (SCT) has been significantly detailed throughout the literature as a means to help manage and predict OR scheduling. However, this information has previously been divided by surgical specialty, and only limited benchmarking data regarding ACT and SCT exists. We hypothesized that advancing the granularity of the ACT and SCT from surgical specialty to specific Current Procedural Terminology (CPT®) codes will produce data that is more accurate, less variable, and therefore more useful for OR schedule modeling and management. This single center study was conducted using times from surgeries performed at the University of Colorado Hospital (UCH) between September 2018 – September 2019. Individual cases were categorized by surgical specialty based on the specialty of the primary attending surgeon and CPT codes were compiled from billing data. Times were calculated as defined by the American Association of Clinical Directors. I^2 values were calculated to assess heterogeneity of mean ACT and SCT times while Levene's test was utilized to assess heterogeneity of ACT and SCT variances. Statistical analyses for both ACT and SCT were calculated using JMP Statistical Discovery Software from SAS (Cary, NC) and R v3.6.3 (Vienna, Austria). All surgical cases ($n = 87{,}537$) performed at UCH from September 2018 to September 2019 were evaluated and 30,091 cases were included in the final analysis. All surgical subspecialties, with the exception of Podiatry, showed significant variability in ACT and SCT values between CPT codes within each surgical specialty. Furthermore, the variances of ACT and SCT values were also highly variable between CPT codes within each surgical specialty. Finally, benchmarking values of mean ACT and SCT with corresponding standard deviations are provided. Because each mean ACT and SCT value varies significantly between different CPT codes within a surgical specialty, using this granularity of data will likely enable improved accuracy in surgical schedule modeling compared to using mean ACT and SCT values for each surgical specialty as a whole. Furthermore, because there was significant variability of ACT and SCT variances between CPT codes, incorporating variance into surgical schedule modeling may also improve accuracy. Future investigations should include real-time simulations, logistical modeling, and labor utilization analyses as well as validation of benchmarking times in private practice settings.

Keywords Healthcare economics · Healthcare value · Operating room efficiency · Surgical case logistics · Operational management · Surgical case estimation

Introduction

Surgical procedures in the United States generate approximately 70% of hospital revenue while accounting for roughly 40% of total costs [1]. Accurate estimation of surgery duration and the concomitant components that make up total surgery time is paramount to ensure operating room (OR) efficiency and control variable costs associated with labor [2]. Typical costs associated with OR utilization can be separated into two main groups: fixed costs (leases, staff salaries

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and benefits, etc.) and variable costs (hourly labor and material costs). Of those variable costs, hourly labor related to overtime compensation comprises the most significant portion. Lowering variable labor costs by enhancing efficient regular OR block utilization results in improved healthcare value (Value = Outcome/Cost). Previous work has defined inputs for OR efficiency and OR utilization (both under- and over-utilization) [3, 4] and has assessed methods for optimizing OR labor utilization. In addition, various time components of a surgical case have been defined to inform assessment of surgical schedule efficiency [5] which contributes to improved staffing models, better OR space utilization, and overall reduction of health care costs [6].

Anesthesia-controlled time (ACT) was initially described by the Association of Anesthesia Clinical Directors as the time during a surgical case that the anesthesiologist can impact case duration efficiency [5]. Since this initial description, many studies have investigated the impact on ACT by various interventions including total intravenous anesthesia (TIVA) versus inhalational anesthesia [7–11], general anesthesia versus regional anesthesia [12–15], the use of a swing room [16], and the presence of trainees [17, 18]. Groups have also investigated how ACT can be used to estimate anticipated total surgical case time and better predict the daily surgical schedule [19–21]. The counterpart to ACT is surgical-controlled time (SCT). This is representative of the time between "anesthesia ready" and the completion of the surgical site closure. SCT has similarly been investigated as a marker of efficiency [22, 23]. The sum of ACT and SCT equates to the total case time.

For an institution to critically evaluate its ACT and SCT data, benchmarking measures must be available. Multiple groups have examined these times with stratification based on surgical subspecialty [20, 24, 25] and one study evaluated ACT values for individual procedures [26]. However, subspecialty stratification of ACT and SCT for the purposes of OR scheduling efficiency is likely inadequate as there can be wide variations in time demands for both anesthesiologists and surgeons for cases even within the same surgical subspecialty. In 1965 the American Medical Association published the first edition of Current Procedural Terminology (CPT®) codes. These standardized codes and terms were a means to code procedures (mainly surgical) for medical records, insurance claims, and information for statistical purposes [27]. By 1983 Centers for Medicare and Medicaid Services (CMS) had mandated adoption of CPT® for use with all procedures related to Medicare part B and subsequently in 1986 for all outpatient procedures [28]. Currently in the United States there are greater than 10,000 codes broken down over three categories, with category one being further divided into 6 sections. Codes are inputted by medical coders, physicians, nurses or industry professionals tasked with the transformation of healthcare diagnoses, procedures, medical services and equipment into universal medical alphanumeric codes. [29].

Here, we provide internal benchmarking data of all surgical procedures performed at our institution as identified by Current Procedural Terminology (CPT®) codes. We hypothesized that stratifying ACT and SCT by primary procedure CPT® code provides enhanced granularity of data that could be used for more accurate operating room schedule efficiency assessment than previously published benchmarks pooled by surgical subspecialty alone.

Methods

Case Selection

All operative cases requiring the services of an anesthesiologist or anesthesia care team performed at the University of Colorado Hospital (UCH) between September 2018 and September 2019 were initially reviewed for inclusion in this study. This included both inpatient and outpatient surgical cases as well as non-operating room cases such as (but not limited to) gastrointestinal endoscopic procedures, interventional radiology procedures, interventional pain procedures, and cardiac electrophysiology procedures. Imaging studies requiring anesthesia (such as magnetic resonance imaging or computed tomography scans) were not included as there is no relevant "surgical control time" for these procedures. Intraoperative data was collected from the Epic electronic anesthesia record system exclusively used at UCH. All cases missing data required to calculate the time periods of ACT and SCT were excluded. Additionally, cases missing an assigned primary surgical attending physician were excluded. Cases were stratified by surgical subspecialty based on the specialty of the primary surgical attending physician. Cases were assigned to a CPT code based on the primary surgical procedure listed and CPT codes with fewer than 30 observations were excluded. This cut-off was chosen to balance the need to be consistent with previously reported studies that used mean and standard deviations while attempting to generalize across CPTs to achieve generally sufficient data to estimate ACTs and SCTs that were not strongly skewed using the central limit theorem [30]. This study was reviewed by the Colorado Multiple Institutional Review Board and the study was approved for exempt status. (COMIRB Protocol 20–2987).

Anesthesia and Surgical Control Time Calculations

Time stamp data was collected on each surgical case evaluated. This included Patient In-Room Time, Ready for Procedure Time (indicating completion of all pre-incision anesthesia-related activities including intubation and invasive line placement), Surgical Incision Time, Close Time (indicating all surgical incisions had been fully closed), and Patient Out-of-Room Time. ACT was calculated as

Table 1 Distribution of Surgical and Anesthesia Control Times by Surgical Specialty. Current study (Simmons et al.) compared to similar results from the literature. All values in minutes

Specialty	Simmons et al		Overdyk et al		Kodali et al		Van Veen Berkx et al	
	SCT (Mean [SD])	ACT (Mean [SD])	SCT (Mean)	ACT (Mean)	ACT – Hospital A (Mean [SD])	ACT – Hospital B (Mean [SD])	SCT	ACT
Cardiac	230.66 [147.77]	42.23 [21.99]	226	47	63.82 [25.63]	49.89 [20.31]	205 [106]	59 [25]
ENT	113.41 [103.61]	22.52 [9.74]	110	30	35.49 [14.80]	31.50 [23.58]	98 [105]	31 [16]
Ophthalmology	38.95 [33.68]	6.13 [6.70]	NR	NR	NR	18.92 [10.55]	56 [35]	21 [12]
General	144.27 [111.77]	23.95 [13.11]	141	31	31.77 [13.85]	27.66 [15.35]	133 [106]	40 [24]
Gynecology	128.78 [106.05]	21.40 [11.99]	130	29	30.39 [11.29]	22.48 [11.25]	105 [83]	33 [17]
Neurosurgery	219.67 [134.92]	34.32 [19.55]	157	34	51.27 [24.92]	41.93 [23.28]	171 [132]	45 [24]
Orthopedic	109.14 [66.08]	20.21 [10.51]	147	33	33.67 [17.82]	32.22 [34.28]	112 [77]	35 [20]
Plastic	125.11 [137.53]	17.84 [11.39]	123	20	31.39 [14.20]	29.51 [14.98]	116 [118]	32 [19]
Thoracic	101.47 [102.70]	25.62 [14.45]	NR	NR	35.15 [18.84]	41.67 [23.69]	NR	NR
Transplant	173.77 [121.48]	29.18 [22.57]	122	27	46.78 [24.56]	48.04 [26.33]	NR	NR
Urology	116.34 [107.84]	22.35 [11.68]	192	35	29.10 [12.91]	25.38 [11.68]	102 [92]	32 [17]
Vascular	136.83 [107.14]	22.75 [15.99]	108	36	40.01 [23.60]	32.77 [11.08]	NR	NR

SCT Surgical Control Time, *ACT* Anesthesia Control Time, *NR* Not Reported, *SD* Standard Deviation, *ENT* Ear, Nose, and Throat

([Ready for Procedure Time]–[In Room Time]) + ([Out of Room Time]–[Close Time]). SCT was calculated as ([Close Time]–[Incision Time]).

Statistical Analysis

The mean and standard deviation for ACT and SCT were calculated, both for the overall surgical specialty and by CPT code within each specialty. The heterogeneity of the mean ACT and mean SCT for the different CPT codes within each specialty were summarized by the I^2 statistic calculated from a meta-analysis with random effect for each CPT code. Values of I^2 range between 0 and 100, with larger values suggesting a large amount of heterogeneity among the given average time for CPT codes within a specialty, whereas values near 0 indicate homogenous mean times. To examine if the variability across CPT codes within a specialty were significantly different Levene's test for homogeneous variance

Table 2a ACT and SCT values for cardiac surgery procedures stratified by CPT code. CPT code only included if n > 30 procedures performed

			SCT		*ACT*	
Specialty	***CPT Code***	***CPT Code***	***Mean***	***SD***	***Mean***	***SD***
Cardiac Surgery	*33510*	CABG Times 1–5	324.81	109.65	51.45	20
	33361	TAVR	131.7	45.54	33.34	16.26
	21627	Sternal Debridement	69.63	52.65	24.91	15.18
	33420	Mitral Valve Replacement/Repair	312.28	111.43	50.39	16.55
	33951	ECMO Cannulation	121.72	69.51	30.44	22.54
	33863	Aortic Root Replacement	337.25	110.91	51	20.42
	33417	Ascending Aortic Aneurysm Repair	379.71	140.03	56.39	20.52
	0451 T	Ventricular Assist Device / Impella / Centrimag Insertion	238.82	123.63	50.49	24.39
	33927	Orthotopic Heart Transplant (including Redo)	361.1	99.43	51.29	18.41
	33390	Aortic Valve Replacement / Repair (including Redo)	301.66	125.83	52.97	23.81
	35820	Post Operative Bleeding Heart	115.34	106.72	28.09	13.88
	20670	Removal Hardware (Sternal Wires)	74.83	78.39	19.33	13.16
	32659	Open Pericardial Window	56.33	12.48	37.67	12.4
	11042	Wound Debridement	39	15.56	18.5	0.71
	All Cardiac Surgery:		230.66	147.77	42.23	21.99

ACT Anesthesia Control Time, *SCT* Surgical Control Time, *CABG* Coronary Artery Bypass Grafting, *TAVR* Transcatheter Aortic Valve Replacement, *ECMO* Extracorporeal Membrane Oxygenation was conducted, where significant p-values indicate the variances in between CPT codes are significantly different. Graphical representations of ACT and SCT by CPT codes were created with forest plots, where the overall mean and 95% confidence interval within a specialty are indicated by darker shaded regions. All analyses were conducted using R v3.6.3 (Vienna, Austria), with p-values < 0.05 being considered significant.

Results

A total of 87,537 cases were reviewed and 30,091 cases were included in the final analysis. A total of 482 CPT codes were excluded for failure to meet the minimum requirement of 30 cases. There were 16 surgical subspecialties included accounting for 205 distinct CPT codes. Table 1 reports the mean (standard deviation) by surgical specialty for ACT and SCT in comparison to other published studies [19, 24, 25]. These publications were identified after an exhaustive literature search as the only publications to list at least ACT and/or SCT for a variety of surgical subspecialties. For example, in cardiac surgery, Overdyk et al. reported a mean ACT and SCT of 47 min and 226 min, respectively, and Van Veen Berkx et al. reported a mean (standard deviation) ACT and SCT of 59 min (25 min) and 205 min (106 min), respectively. Whereas, our current investigation reported 42.23 min (21.99 min) and 230.66 min (147.77 min) for ACT and SCT, respectively.

Tables 2a (cardiac surgery) and 2b (neurosurgery) presents the individual mean (SD) ACT and SCT for the most frequently observed CPT codes within these surgical subspecialties. These two surgical subspecialties were chosen to highlight the variability in ACT and SCT within each specialty especially when compared to each specialty's respective summary statistics. For example, the mean (standard deviation) ACT and SCT values for all neurosurgical procedures was 34.32 (19.55) minutes and 219.67 (134.92) minutes, respectively. However, the range of mean ACT values for all CPT codes within neurosurgery was 15.47 – 45.38 min, and the range of mean SCT values for all CPT codes within neurosurgery was 55.32 – 281.04 min. Similarly, for cardiac surgery, the mean (standard deviation) ACT and SCT values for all procedures were 42.23 (21.99) minutes and 230.66 (147.77), respectively; the ranges of mean ACT and SCT values were 18.50 – 56.39 min and 39.00

Table 2b ACT and SCT values for neurosurgery procedures stratified by CPT code. CPT code only included if n > 30 procedures performed

			SCT		*ACT*	
Specialty	***CPT Code***	***CPT Code***	***Mean***	***SD***	***Mean***	***SD***
Neurosurgery	*61304*	*Craniotomy*	*281.04*	*126.59*	*40.03*	*20.2*
	63001	*Cervical Spine Surgery (Anterior or Posterior or Anterior / Posterior)*	*225.46*	*122.57*	*42.73*	*19.04*
	61888	*Replacement DBS Generator*	*55.32*	*15.64*	*15.47*	*7.06*
	63005	*Lumbar Laminectomy*	*168.68*	*65.43*	*27.29*	*11.08*
	63030	*Lumbar Spinal Surgery (Posterior or Anterior / Posterior)*	*304.12*	*139.14*	*33.36*	*14.92*
	61546	*Transsphenoidal Resection Pituitary Tumor*	*158.45*	*63.17*	*32.71*	*10.19*
	62160	*Insertion vs Revision vs Removal VP Shunt*	*121.13*	*42.7*	*26.82*	*9.74*
	61850	*Insertion DBS / Craniotomy Neuropace*	*222.78*	*98.68*	*34.98*	*20.95*
	22511	*Thoracic Spine Surgery (Posterior)*	*341.85*	*145.01*	*38.11*	*13.91*
	61526	*Craniotomy Acoustic Neuroma*	*456.54*	*121.11*	*45.28*	*20.58*
	61697	*Craniotomy Aneurysm Clip Ligation*	*250.31*	*55.69*	*44.64*	*46.25*
	61885	*Insertion DBS Generator*	*92.4*	*41.48*	*23.93*	*8.25*
	61534	*ROSA or Visualase Procedure*	*247.43*	*81.49*	*45.38*	*21.67*
	61250	*Craniotomy Hematoma Evacuation*	*158.47*	*49.13*	*27.32*	*12.62*
	62164	*Endoscopic Resection Skull Base Tumor*	*182.29*	*77.85*	*34.32*	*10.49*
	10180	*Spine Incision and Drainage*	*134.64*	*50.06*	*31.5*	*20.7*
	11042	*Wound Debridement*	*111.72*	*45.4*	*26.39*	*10.05*
	22533	*Extreme Lateral Interbody Fusion*	*320.45*	*151.11*	*31.73*	*9.31*
	22224	*Lumbar Spine Surgery (Anterior)*	*221.27*	*109.6*	*26.73*	*14.75*
	31231	*Functional Endoscopic Sinus Surgery*	*198.43*	*105.71*	*25.57*	*8.77*
	All Neurosurgery:		*219.67*	*134.92*	*34.32*	*19.55*

ACT Anesthesia Controlled Time, *SCT* Surgical Controlled Time, *DBS* Deep Brain Stimulator, *VP* Ventriculoperitoneal, *ROSA* Robotic Stereotactic Assistance

– 379.71, respectively. ACT and SCT values for individual CPT codes within other subspecialties can be located in the Supplemental Materials as Table 4.

SCT and ACT were different across CPT codes within each specialty for both mean time and associated variability. See Figs. 1 (SCT) and 2 (ACT) for visual representation. Bars indicate 95% confidence interval of each surgical control time per CPT code while points display the mean. Grey boxes denote the overall confidence interval for the surgical control time per specialty and dotted line is the overall mean. Table 3 statistically illustrates this, where no specialty within SCT has an I^2 below 90% and within ACT below 99% suggesting a high degree of heterogeneity within each specialty for the average time across CPT codes and highly variable SCT and ACT between CPT codes within surgical specialty. Further, Levene's test is $p < 0.001$ for all specialties within ACT and SCT, indicating the variability across CPT codes within each group is significant and there is a lack of homogeneity of variance. The high I^2 values depicted in Table 3 indicates highly variable surgical and anesthesia control time between CPT codes within specialty. Corresponding *p*-values for each subspecialty indicates lack of homogeneity of variances. (Table 3).

Discussion

The elective surgical schedule and overall operating room utilization has significant financial and operational implications for healthcare systems. Thus, the ability to better predict an elective surgical schedule can potentially improve OR management, increase revenue from surgical volume if additional surgical cases can be completed in a specified block of time, and decrease excessive labor costs associated with inefficient staffing models. Analyzing procedure duration by respective ACT and SCT values has been previously studied as a method to better estimate procedure duration. However, these prior studies have only subcategorized ACT and SCT by surgical subspecialty (e.g. cardiac or orthopedic surgery). This study explores SCT and ACT categorized by

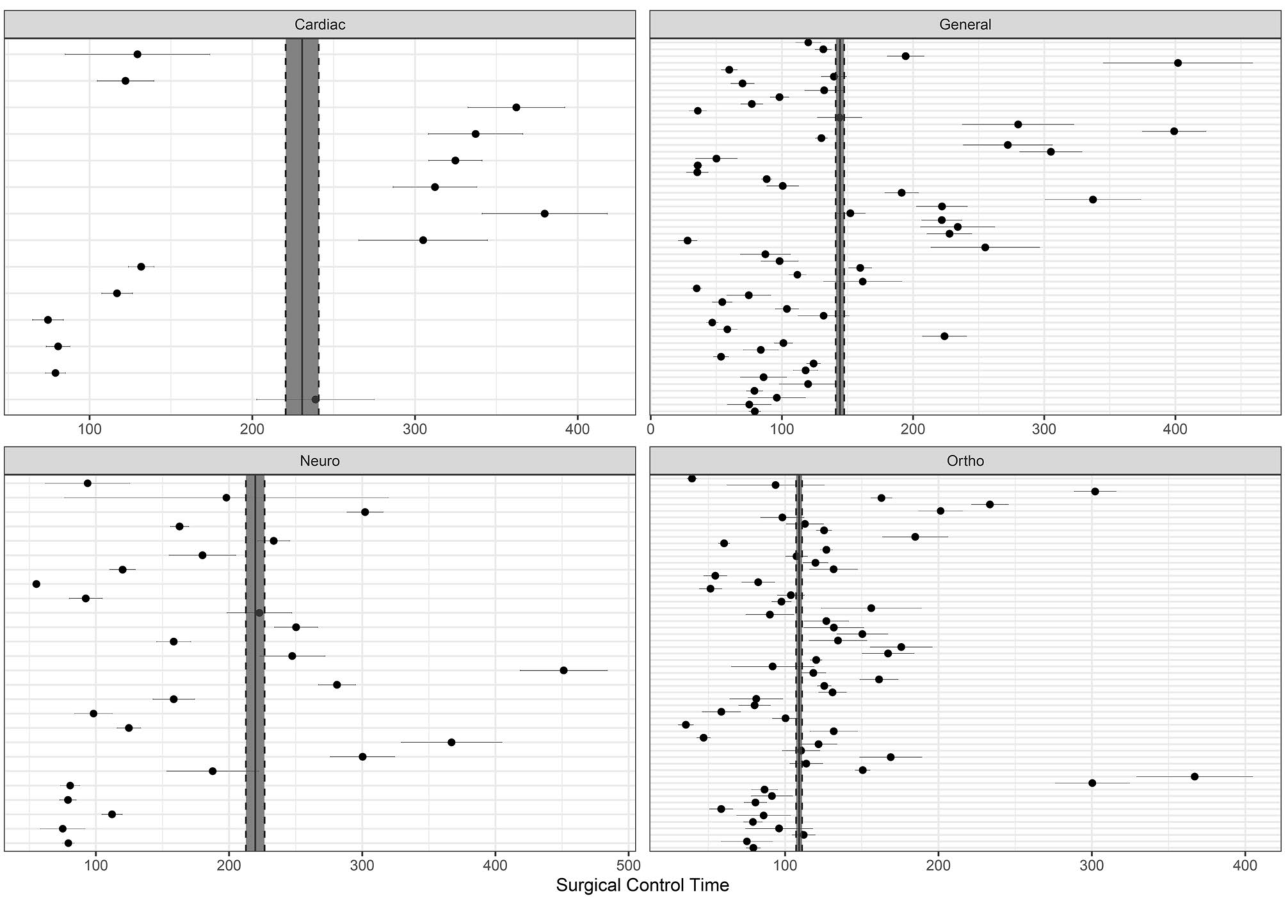

Fig. 1 Individual CPT codes within each specialty are plotted on the y−axis. The mean and standard deviation SCT time for each CPT within each specialty are plotted on the x−axis respective to the CPT code. Dots are the mean and bars are the standard errors. The vertical dotted lines represent standard deviation for the average SCT time across all CPT codes in each specialty. Solid black line represents the mean for the SCT time across the entire specialty

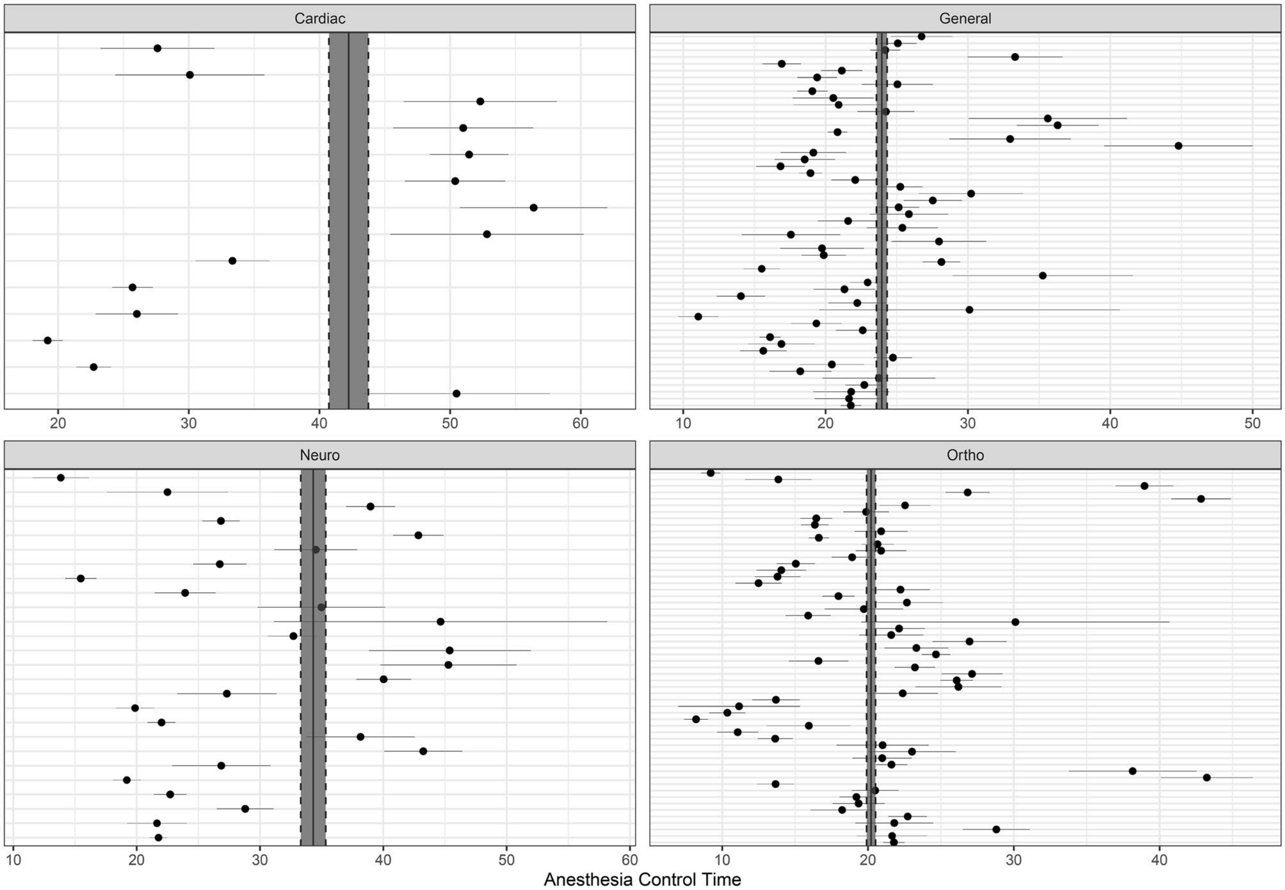

Fig. 2 Individual CPT codes within each specialty are plotted on the y−axis. The mean and standard deviation ACT time for each CPT within each specialty are plotted on the x−axis respective to the CPT code. Dots are the mean and bars are the standard errors. The vertical dotted lines represent standard deviation for the average ACT time across all CPT codes in each specialty. Solid black line represents the mean for the ACT time across the entire specialty

CPT code, and to our knowledge, the first to compare CPT code-derived SCT and ACT to aggregated ACT and SCT values for each surgical subspecialty.

We found that mean anesthesia and surgical control times vary significantly based on procedural CPT code and this heterogeneity extends to analysis of CPT codes within surgical subspecialties. Furthermore, we found a lack of homogeneity when examining the variances of ACT and SCT between CPT codes within a given surgical subspecialty. Taken together, this investigation provides for possible benchmark values for both SCT and ACT for a variety of CPT codes across multiple surgical subspecialties and suggests that using ACT and SCT values by CPT code would generate a more accurate total OR utilization data compared to using mean ACT and SCT values based only on surgical subspecialty.

Through this investigation, we demonstrate that subcategorization of ACT and SCT by surgical subspecialty lacks the granularity needed to understand, and potentially predict, accurate procedure time. Indeed, the I^2 values for all subspecialty SCT and ACT are high indicating significant heterogeneity between CPT codes. I^2 values for SCT and ACT were also significantly elevated for all surgical subspecialties studied. We argue this indicates that using mean SCT and ACT values for an entire surgical subspecialty is inadequate for informing an elective surgical schedule, and instead, mean SCT and ACT values for each CPT code should be used.

This intuitively makes sense when considering the wide breadth of procedures each surgical subspecialty may perform. For example, in neurosurgery, the shortest procedure was Replacement of a Deep Brain Stimulator Pulse Generator (CPT code 61,888) with a mean ACT of 15.47 and a mean SCT of 55.32 min while the longest procedure was Image Guided Craniotomy (CPT code 61,304) with a mean SCT of 281.04 min and a mean ACT of 40.03 min. Clearly, describing all neurosurgical procedures as having a mean SCT of 205.13 min and mean ACT of 33.87 min inadequately addresses the variability in both of these values. The mean times would overestimate the total mean OR time

Table 3 I2 value per specialty for each surgical control time and anesthesia control time. P-values are based on the Levene's test for heterogeneity of variance. The high I2 value indicates highly variable surgical and anesthesia control time between CPT codes within specialty. The p-value indicates lack of homogeneity of variances

	Surgical Control Time		Anesthesia Control Time	
Specialty	I^2	P-value	I^2	P-value
Ortho	99.5 (99.4, 99.5)	< 0.0001	98.8 (98.8, 98.9)	< 0.0001
General	99.8 (99.8, 99.8)	< 0.0001	98.1 (98.1, 98.3)	< 0.0001
Urology	99.9 (99.9, 99.9)	< 0.0001	96.6 (97.3, 97.7)	< 0.0001
Gyn	99.9 (99.9, 99.9)	0.0002	98 (97.8, 98.1)	0.003
Cardiac	99.6 (99.6, 99.7)	< 0.0001	97.6 (97.4, 97.8)	< 0.0001
Plastics	99.9 (99.9, 99.9)	< 0.0001	99.2 (99.1, 99.3)	< 0.0001
Neuro	99.8 (99.8, 99.8)	< 0.0001	98.6 (98.4, 98.7)	< 0.0001
Thoracic	99.9 (99.9, 99.9)	< 0.0001	98.4 (98.3, 98.6)	< 0.0001
ENT	99.6 (99.6, 99.6)	< 0.0001	94 (94.5, 95.3)	< 0.0001
Vascular	99.3 (99.3, 99.4)	< 0.0001	98.4 (98.1, 98.5)	< 0.0001
Spine	99.6 (99.6, 99.6)	< 0.0001	98.1 (97.9, 98.3)	< 0.0001
Eye	100 (100, 100)	< 0.0001	99.6 (99.6, 99.7)	< 0.0001
Transplant	99.9 (99.9, 99.9)	< 0.0001	99.7 (99.7, 99.7)	< 0.0001
Breast	99.4 (99.3, 99.5)	< 0.0001	96.5 (96.1, 97.2)	< 0.0001
Podiatry	88.6 (88.4, 93.7)	0.395	87.2 (85, 91.1)	0.862
Other	97.8 (93.7, 99.7)	0.266	97.3 (92.3, 99.7)	0.294

needed for a Pulse Generator Replacement but underestimate the mean OR time needed for an Image Guided Craniotomy, thus creating not only an inaccurate schedule but potentially patient, provider, and staff dissatisfaction. This can be seen in other surgical subspecialties, as well. For example, the shortest vascular surgery procedure was Vein Ligation and Stripping (CPT code 37,650) with a mean SCT of 85.57 min and a mean ACT of 14.16 min while the longest vascular surgery procedure was Abdominal Aortic Aneurysm Repair (CPT code 34,701) with a mean SCT of 253.06 min and a mean ACT of 34.58 min. Using the overall vascular surgery mean SCT of 155.12 min and mean ACT of 23.61 min would be inadequate to describe either of these individual procedures when creating a surgical schedule.

Efficient personnel utilization is required for healthcare organizations to minimize cost and maximize revenue. Inaccurate projection of surgery duration directly impacts daily OR scheduling and creates mismatch of OR utilization and staffing levels. Our study adds to the already significant resources that attempt to provide OR managers and schedulers with the tools needed to optimize staffing in relation to planned procedures and the accompanying anticipated operating room usage on a daily basis. However, unlike other prior publications, this study provides enhanced data granularity in a format that has the potential to further enhance efficiency without requirements for cumbersome data analytics functions.

A recent publication attempted to utilize predictive analytics and artificial intelligence technology to enhance operating room efficiency [31]. However, most models and currently utilized technology rely on strategies and input variables that are inherently inefficient: surgical subspecialty, surgeon, past-performance, etc. [31, 32] This lack of granularity prevents healthcare systems from implementing processes that allow for maximum OR efficiency. Our method of using CPT codes demonstrated extreme heterogeneity and variance for both ACT and SCT. This finding validates our original hypothesis that subspecialty mean SCT and ACT are not an adequate approximation for time needed to complete anesthesia and surgical tasks across for all CPT codes that fall under a given subspecialty.

We acknowledge that there are several limitations which must be considered when interpreting the results from this research. This study does not account for individual surgeon time variance for a particular CPT code surgery. Even though this was a large dataset, a significant surgeon outlier for a particular CPT code could skew the mean SCT. Not all surgeons are capable of performing a specific surgery in the same amount of time and occasionally the primary CPT code does not accurately describe the surgery performed. In addition, patient comorbidities such as obesity, valvular heart disease, COPD, OSA can lend themselves to the need for more extensive intraoperative monitoring or difficulty with induction and the surgery itself. Further analysis using ASA classification could further increase the granularity of the data and result in more accurate estimations of ACT and SCT timings [33].

The second limitation of this study is generalizability. The data collection was performed only at a single center which is a Level 1 Trauma Center, quaternary care academic institution with trainees in both surgery and anesthesiology. All anesthetic care at UCH is performed under medical direction with one attending anesthesiologist supervising up to four certified registered nurse anesthetists or anesthesiologist assistants, or up to two residents.". It is rare that an attending anesthesiologist personally performs the anesthetic. As surgeries in academic institutions are noted to be longer in length compared to non-academic settings, it is possible the ACT and SCT averages based on CPT codes will not accurately describe surgery in a community hospital or an institution without trainees [34]. Further analysis of ACT and SCT in settings without trainees should be performed and compared to this analysis. Additionally, as this study was performed with the data from a quaternary care academic institution, there were 687 primary CPT codes assessed but only 205 of them were analyzed as 482 of the CPT codes had less than 30 observations during the study period. We had excluded these CPT codes due to the smaller sample size and lower likelihood of normality of the data based on the central limit theorem [30]. With smaller sample sizes, there is a higher risk of skewed data resulting in inaccurate summary statistics of the ACT and SCT values. As such we have only provided the values of ACT and SCT for the CPT codes with more than 30 observations in this manuscript as these values hold the most utility for schedulers and OR managers. In a future study, we plan expand on this analysis by assessing a longer time period with the hopes to have more observations for each CPT code, allowing accurate summary statistics of more procedures. In addition, we also plan to analyze additional academic institutions, community hospitals and ambulatory surgical centers.

A third limitation of this study is the use of means instead of medians for statistical analysis. Historically, anesthesia-controlled time has been more commonly described using means with standard deviation even though the data is not normally distributed [7, 8, 11, 17]. This is the first retrospective study to our knowledge that analyzes both ACT and SCT based on CPT codes instead of surgical subspecialties. By utilizing means and standard deviations, we were able to compare our data with previous studies which only focused on ACT, however further research should directly examine whether CPT code-based scheduling can impact surgical scheduling, operating room efficiency and can improve staffing need predictions for perioperative services.

Conclusion

Efficient utilization of operating rooms is required for healthcare organizations to appropriately schedule surgical cases, predict staffing needs, and minimize costs. Which in turn leads to enhanced healthcare value, increased revenue and improvement of patient, provider and staff satisfaction. Average anesthesia and surgical control times based on surgical subspecialty have been studied extensively and are used to guide operating room scheduling. However, our study revealed significant heterogeneity for ACT and SCT within surgical subspecialty and suggests that using primary procedure CPT code may provide improved data granularity for estimating ACT and SCT. Future work should include comparisons of academic settings to private practice and modeling of CPT code-based scheduling impact on OR utilization efficiency and staffing requirements.

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Declarations

Conflicts of Interest The authors declare no competing interest.

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