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January 1996

The Comparative Health Care Policy Research Project

Asia/Pacific Research Center

Stanford University

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Stanford, CA 94305-6055

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Acknowledgments

This work was supported by an endowment established by the Council for Better Corporate Citizenship, Tokyo, Japan. The project was also supported by the Pfizer Health Research Foundation, Tokyo, Japan, and by Global Health Institute, Menlo Park, Ca.

We would like to acknowledge the support of Akira Furuse, M.D. and Toshiko Nagase.

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Introduction

One of the most persistent and important questions in international comparisons of health systems pertains to the wide divergence in costs between countries. Japan has significantly lower per capita health care costs than does the United States, despite having a fee-for-service reimbursement system and universal coverage, and aggressively purchasing and utilizing equipment-embodied medical technologies.[1] One important factor in the increase in American health care costs over time has been the substitution of surgical intervention for medical treatment.[2] This leads us to consider differential rates of surgery as a potential explanation for divergent cost performances. Indeed, although Japan has one-half the inpatient admission rate of the United States, it has only one-quarter the surgery rate per capita.[3]

In order to understand more completely the reasons for the differences in surgical rates between the United States and Japan, we present a case study comparing data derived from the University of Tokyo and Stanford University Hospitals' information systems. Our primary purpose in undertaking this research is to investigate the volume and length of surgical operations at the two hospitals, to decompose these differences into their component parts, and to use this information in explaining surgical procedures in terms of social, economic, and practice-style differences between the two countries.

There are a number of important differences in the health care delivery systems of Japan and the United States that potentially confound the results of comparative studies. These factors include the substitution of acute hospital care for nursing home care in Japan, differences in hospital ownership structure and financing arrangements, and differences in disease prevalence.[4] Because they have similar delivery systems and missions, we focus on teaching hospitals in order to control for the effects of some possible confounding influences. Stanford University Hospital and the University of Tokyo Hospital occupy similar positions in their respective countries; they are technology-intensive, tertiary care teaching institutions with reputations for quality medical care delivery and research.

This case uses patient-specific data to analyze case-mix adjusted durations for surgeries in the two hospitals. We examine surgical operations by pre-operative time (hereafter pre-op), operative time, post-operative time (hereafter post-op), and idle time. By looking at the time allocations for similar procedures and across similar patients, we hope to pinpoint the sources of the volume differentials between the two hospitals.

Because in-depth studies of Tokyo and Stanford have been reported elsewhere,[5] we provide only a brief summary of relevant hospital characteristics. Stanford operating rooms (hereafter OR) can be divided into two categories. There are 20 rooms in the main OR and 8 in the ambulatory surgery center (ASC). As the names suggest, the main ORs primarily serve hospital inpatients, while the ASC primarily serves hospital outpatients, providing same-day surgeries. In contrast, Tokyo does not perform outpatient surgery in its 13 OR suites and does not perform a significant number of outpatient surgeries elsewhere in the hospital.

In the Stanford main OR, 6,045 procedures were performed from January to June 1993 (302 operations/room). Over this period, 2,724 operations were performed in the Stanford ASC (341 operations/room). At Tokyo, 2,318 procedures were performed in 12 rooms over the same period of time (193 operations/room). In sum, Tokyo's surgical volume was just over one-fourth that of Stanford, paralleling the aggregate difference in volume between the two countries. The Tokyo figures may overstate the number of operations per room because one of its rooms has two operating tables. A comparison of per-table operations reveals that Stanford performs 313 operations/table, nearly twice Tokyo's 178 operations/table.

Data and Methods

The data used in this study are derived from surgical patients at Tokyo and Stanford from January 1, 1993 to June 30, 1993. During this period, there were a total of 8,769 patients at Stanford and 2,318 at Tokyo. The available data contain descriptions of the room used, the procedures performed, the times that the patient entered and left the OR, the times of the incision and closure, and demographic information for each patient. We derive and compare pre-op, post-op, and operating times at Stanford and Tokyo, while adjusting for observed case-mix differences.

In 1993, Stanford used an in-house coding system based loosely upon the American Medical Association's CPT codes, while Tokyo used the World Health Organization's International Classification of Procedures in Medicine (ICPM) codes. Since the two hospitals used different classification systems to categorize operations, and since there is no mapping program available from Stanford's in-house system to ICPM codes, we created a unified coding scheme by which to match procedures between the two institutions. This scheme consists of major subheadings from the ICPM code book, a system largely organized by organ systems. The unified scheme classifies procedures into considerably fewer detailed categories than do the parent schemes used by the two hospitals.

The advantage of this approach is that any given procedure, regardless of how it is recorded by the hospitals, will be mapped to the same place in the more aggregated, unified scheme. Attempting to define a direct map would have created more distortions because the parent schemes differ along different dimensions of detail in ways that do not naturally nest. The drawback of aggregation is that it ignores details which often contain potentially important information regarding the difficulty of a procedure. However, the aggregated unified scheme maintains the feature of distinguishing broad case-mix distinctions.

An important difference between the two hospitals is that Stanford has both ambulatory and main OR facilities. Of the 8,769 Stanford operations covered in this study, 2,725 (31.1%) were conducted in the ambulatory rooms. Tokyo does not perform ambulatory surgery, and since there is no way to determine which of Tokyo's patients would have been operated on in an outpatient setting at Stanford, we cannot separate Tokyo's data into categories corresponding to Stanford's main and ambulatory categories. It would not be appropriate to exclude Stanford's ambulatory patients, because the corresponding patients are operated upon in an inpatient setting in Tokyo. For example, at Stanford most cataract surgery is performed in the ASC on an outpatient basis, while at Tokyo such surgery is universally performed on an inpatient basis. To exclude Stanford's outpatient cataract surgery from the analysis would likely bias the Stanford figures toward longer operations, as only more severely ill patients would be included.

The Stanford data are also divided into faculty-performed and community physician-performed operations. Stanford gives surgical privileges to non-faculty practitioners, so not all of its operations involve a significant teaching component. In fact, 47% of all Stanford surgeries are performed by non-faculty practitioners (although only 37% of the main OR operations are performed by non-faculty). To maintain comparability of data, we exclude surgeries performed by non-faculty members. After this restriction, there remain 4,612 cases at Stanford to analyze. This division of the Stanford data is justified by reports of important case-mix and severity differences between teaching and non-teaching hospitals in general,[6] and faculty and non-faculty practitioners in particular.[7] We need not make this distinction for Tokyo, since the closed medical staff system there ensures that only faculty physicians perform operations.

The Tokyo data are partitioned into Type I, II, and III patients. Types I and II are surgeries utilizing general anesthesia. Patients undergoing Type I procedures are moved from the operating theater to the recovery area within the center; these patients are subsequently moved either to a general ward or to the surgical ICU as necessary. In contrast, the Type II patients remain in the OR and then are moved to the surgical ICU. Type III patients receive local anesthesia only. This distinction is relevant largely for descriptive purposes.

We matched data from Stanford and Tokyo by the department that performed the operation. In most cases, it is obvious how departments map from one institution to another. But in some instances, departments are combined to maintain a consistent definition of departments across institutions. This has the added advantage of potentially maintaining similar operations within the same departments across the two institutions.

The principal objects of interest in the study are pre-op, operation, post-op, and idle times. These times are illustrated in Figure One. Pre-op time is the time between patient entry into the operating room and incision. Operative time measures the interval between incision and closure. Post-op time is the period between closure and patient exit from the OR, either to the recovery room or to the ICU. Finally, idle time begins at patient exit from the room and concludes with the entry of the next patient.

In addition to providing evidence about differences in surgical volumes and operation lengths between Japan and the United States, these quantities are of independent interest. For example, such information is of value for planning the optimal number of operating rooms in a hospital surgical suite[8] and for devising an optimal scheduling algorithm.[9] Furthermore,

Figure 1: Flowchart of Time Variables

* Down time is 24 hours minus the in-room time usage. Specifically, it is 24 hours minus total idle times and the time after the last operation of one day and prior to the next operation.

these quantities can be used to calculate common measures of operating room efficiency.[10]

We have determined age, sex, and case-mix-adjusted pre-op, post-op, and operation times for Tokyo and Stanford. Case mix is standardized by age category, gender, and primary procedure.

Additionally, three sets of case-mix weighting were developed: one constructs weights using only Stanford data; one does so using only Tokyo data; and one combines the two. For each of these alternatives, the full complement of operations is partitioned into age-sex-case cells. The age categories are newborn (one week or less), greater than one week but less than 6 years, 6-20 years, 21-40 years, 41-60 years, and greater than 60 years. The number of operations that fall into each cell are counted and divided by the total number of operations. These fractions are then used as weights in calculating the age, sex, and case mix-adjusted weighted averages which are reported below. Though we calculate these weighted means employing all possible permutations of weights, we use the combined weights for overall comparison in the discussion. The absolute value of the time differentials across the different weighting systems is small.

Results

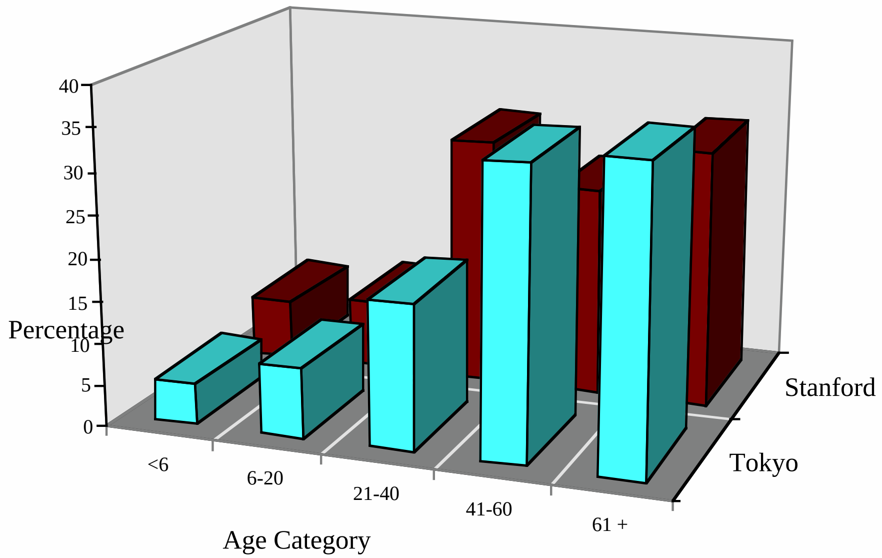
Raw OR times for Stanford faculty physicians and all Tokyo physicians are presented in Table One. Average operation time is 122 minutes at Stanford and 165 minutes at Tokyo ($p<.001$), while mean non-operation in-room time is 53 minutes at Stanford and 73 minutes at Tokyo ($p<.001$). Raw pre-op and post-op times differ by 13 ($p<.001$) and 8 ($p<.001$) minutes respectively between the two institutions. Our principal purpose in the remainder of the paper will be to determine the contributions of case mix, patient demographics, and scheduling in explaining these differences.

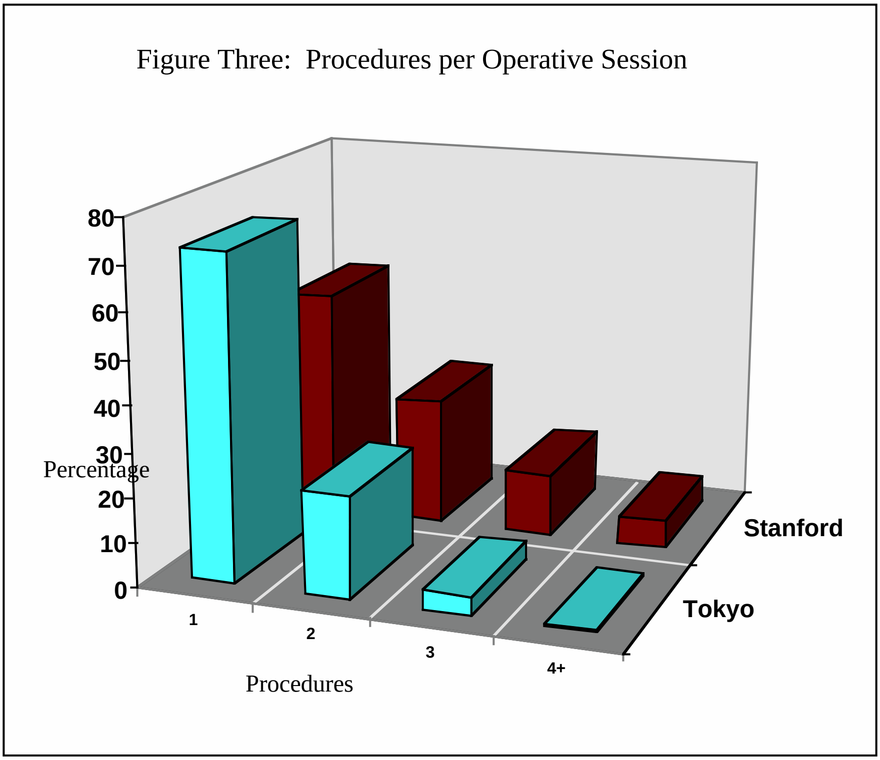
Figure Two presents summary demographic data. It shows that Tokyo has an older patient population than does Stanford. Furthermore, the proportion of men and women differs between the two hospitals; Stanford's patients are 46.8% men, while Tokyo has 53.9%. These differences notwithstanding, our ability to analyze the data at the level of the individual patient allows us to control for the case-mix differentials.

Table One: Raw OR Times, Stanford Faculty vs. Tokyo (minutes)

		Cases	PreOp (s.d.)	Operation (s.d.)	PostOp (s.d.)
Stanford	All	4612	40.2 (25.8)	122.3 (108.0)	12.6 (30.5)
	Main	3834	42.8 (27.1)	132.1 (113.6)	13.4 (33.3)
	Ambulatory	778	27.3 (11.9)	73.7 (51.4)	8.4 (7.0)
Tokyo	All	2318	52.8 (27.2)	164.5 (161.5)	20.6 (17.1)
	Type I	1369	50.6 (27.4)	170.5 (131.2)	19.9 (14.2)
	Type II	544	60.2 (30.4)	284.8 (245.4)	34.5 (23.3)
	Type III	405	52.7 (23.1)	59.7 (35.0)	11.9 (10.5)

Figure Two: Age Structure





In Figure Three, we highlight the differences in the number of procedures performed per operative session between Stanford and Tokyo. As the figure shows, Stanford physicians perform substantially more procedures per operation. It is important to note that Stanford does not record more than four procedures per operation, so that the actual difference in the number of procedures is even greater than the one we present. Our results present time per operative session, not per procedure, since procedure time is not recorded. Clearly, operation time per session overstates Stanford's time per procedure more so than it does Tokyo's.

Table Two lists the 20 most frequently performed procedures at Tokyo and in the Stanford main OR. Note that the top three Tokyo procedures are cataract-related and that eight of the top twenty operations are

Table Two: Twenty Most Frequently Performed Procedures

Stanford Main	Cases	Tokyo	Cases
Exploration of Bowel	299	Insertion of Prosthetic Lens	229
Cytoscopy	255	Other Cataract Extraction	202
Inguinal Hernia Repair	181	Facilitation of Intraocular Circulation	113
Open Skull Exploration	175	Craniotomy	74
Insertion of Vein Catheter	136	Myringoplasty	60
Laminectomy	124	Repair of Inguinofemoral Hernia	52
Diagnostic Pelvic Laproscopy	119	Cholecystectomy	52
CABG; single vein	114	Other Retina Repair Operations	46
Total Hip Procedure	114	Other Free Skin Grafts	44
Removal of Orthopedic Hardware	114	Other Scleral Buckling	44
Breast Biopsy Incisional	114	Scleroplasty	44
Discectomy	112	Partial Gastrectomy	40
Appendectomy	111	Vitreous Operations	36
Pelvic Lymphadenectomy	105	Classical Cesarean Section	35
Skin Tissue Procedure	102	Other Larynx and Trachea Operations	33
Diagnostic Bronchoscopy	99	Extracapsular Extraction of Lens	33
Radical Prostatectomy	96	Replacement of Heart Valve	32
Endoscopic Cholecystectomy	96	Other Nasal Sinus Operations	32
Abdominal Surgery; unspecified	95	Partial Excision of Large Intestine	30
Laser Prostatectomy	93	Regional Lymph Node Excision	28

ophthalmic. Cataract surgeries are performed, for the most part, at Stanford's ASC, on an outpatient basis.

Pre-op, operation, and post-op times are presented for the main center and the ambulatory surgery center by department in Table Three. The table shows that operations performed in the ambulatory surgical suites are without exception shorter, on average, than their main OR counterparts. In addition, the pre-op and post-op times are considerably shorter in the ASC. This pattern is reflective of the case-mix differences between the two centers, with the ASC specializing in outpatient surgeries.

Table Three: Stanford Faculty OR Times, Main and Ambulatory (minutes)

	Main			Ambulatory		
Department	PreOp	Operation	PostOp	PreOp	Operation	PostOp
General	34.1	131.7	10.8	21.9	63.8	6.9
Neurosurgery	60.4	163.8	15.2	N/A	N/A	N/A
Cardiac/Thoracic	58.4	163.3	12.7	N/A	N/A	N/A
Orthopedic	45.6	136.6	17.4	28.0	83.9	9.7
ObGyn	37.1	139.6	12.6	26.6	78.8	8.8
Opthalmic	29.4	103.3	8.9	25.4	56.3	6.2
Urology	33.9	111.9	10.5	24.5	57.4	5.6
ENT	30.0	136.0	18.8	19.6	58.2	12.4
Plastic/Reconstructive	38.9	112.2	12.9	32.2	84.5	8.4
General Pediatric Surgery	31.5	67.7	13.3	N/A	N/A	N/A
Others	35.1	69.0	10.4	31.5	94.1	8.5

In Table Four, pre-op, operation, and post-op times are presented for Tokyo by department. For most departments, Stanford surgeries have shorter times; this is true even if one focuses only on the Stanford main OR. For example, operative time for general surgery at Stanford is 120 minutes, while at Tokyo it is 222 minutes ($p<.001$). However, Tokyo is speedier in some departments. Ophthalmic surgery is one of these; Stanford physicians complete an average operation in 72 minutes, while Tokyo physicians take 55 minutes ($p<.001$). These patterns hold up for the pre- and post-operative times as well.

Table Four: Tokyo OR Times (minutes)

Department	PreOp	Operation	PostOp
General	54.4	222.1	25.2
Neurosurgery	61.5	252. 6	32.9
Cardiac/Thoracic	77.3	355.8	30.4
Orthopedic	70.9	224.8	27.9
Ob/Gyn	49.0	135.1	20.1
Ophthalmics	54.8	68.0	12.0
Urology	59.3	156.8	25.8
ENT	37.3	132.8	16.5
Plastic/Reconst.	45.2	188.8	19.1
Pediatric	32.3	85.5	16.2
Oral	38.3	170.5	16.4
Others	66.7	141.6	20.7

It is also interesting to note the similarities between the two institutions in the distribution of times within the operative episode. In particular, Stanford spends 27.5% of the total in-room time on pre-op, 63.3% on operation, and 9.2% on post-op. Similarly, Tokyo spends 29% (p<.001), 60.6% (p<.001), and 10.4% (p<.001), respectively. While these differences are significant, their magnitudes are small. These similarities show that the time differences between Stanford and Tokyo are not concentrated in any particular part of the in-room time, but are rather diffused through all three of the relevant intervals.

In Tables Five and Six, the case-mix adjusted times appear for Stanford and Tokyo. These tables report utilization time adjusted for procedure, gender, and age. After these adjustments, the differences in pre-op, operation, and post-op times remain. Tokyo utilizes 11.8 (p<.001), 41.6 (p<.001), and 9.0 (p<.001) more minutes in pre-op, operation, and post-op times per operative session. From these tables, we can see that crude case-mix cannot account for all of the differences we observed earlier in operative times.

Table Five: Stanford Faculty Case-mix Adjusted Averages* (minutes)

	PreOp (s.d.)	Operative (s.d.)	PostOp (s.d.)
All	34.3 (26.7)	100.8 (91.2)	10.7 (25.3)
Main	36.0 (27.9)	114.8 (92.5)	12.0 (30.6)
Ambulatory	21.8 (11.1)	52.0 (38.1)	6.4 (5.6)

* A procedure is included if both Tokyo and Stanford perform at least twenty.

Table Six: Tokyo Case-mix Adjusted Averages* (minutes)

	PreOp (s.d.)	Operative (s.d.)	PostOp (s.d.)
All	46.1 (22.1)	142.4 (102.3)	19.7 (16.9)
Type I	43.3 (20.1)	175.1 (120.1)	21.0 (14.8)
Type II	53.2 (26.8)	280.3 (190.2)	35.4 (22.4)
Type III	41.7 (19.9)	50.3 (22.6)	11.2 (9.9)

Table Seven: Stanford Faculty, Tokyo Procedure Results* (minutes)

	Stanford			Tokyo		
Procedure	PreOp	Operative	PostOp	PreOp	Operative	PostOp
Endoscopy	29.29	76.09	10.02	43.35	92.95	18.05
Brain, Nerve, & Skull	52.80	162.55	15.06	61.36	266.36	31.77
Endocrine Operations	33.40	125.50	10.58	44.09	221.09	21.26
Eye Operations	26.82	70.54	7.20	54.66	65.02	11.88
Ear Operations	24.14	90.98	28.15	41.03	147.39	14.03
Nose, Mouth, & Pharynx	29.11	87.41	11.86	41.04	128.13	15.73
Respiratory System	45.27	152.82	14.14	34.61	146.33	22.76
Cardiovascular System	60.94	175.41	13.31	71.01	316.68	26.16
Digestive Tract	29.89	96.62	10.17	49.57	203.60	23.95
Urinary Tract	37.26	138.02	11.06	58.87	169.02	29.44
Male Genital Organ	34.84	128.05	11.17	48.78	90.8	15.15
Female Genital Organ	37.26	105.02	10.44	53.15	151.34	20.75
Musculoskeletal	37.30	96.01	10.98	66.44	221.91	26.13
Breast Operations	30.21	139.68	13.34	47.24	190.41	21.41
Skin and Subcutaneous	34.98	99.13	11.78	51.97	163.85	19.06

* A procedure is included if both Tokyo and Stanford perform at least twenty.

In Table Seven, we present operative session times for a number of frequently performed procedures that are coded by the unified scheme at the two institutions. These figures further bear out the differences noted previously. In most cases, Stanford exhibits shorter times during an operative session than does Tokyo, and these differences are diffused throughout the operative session.

Tables Eight and Nine report the distribution of idle time and room utilization by day of the week at Stanford and Tokyo. In Table Eight, it is apparent that Stanford has greater average idle time between patients. This phenomenon is explained by two factors, both related to scheduling. First, there are many more cancellations at Stanford, approximately 2 to 4 per day, while there were only 50 cancellations over the entire sample period of six months at Tokyo. Second, physicians at Stanford are able to reserve specific times and rooms for their patients, and the OR department must schedule around these “physician demand times.” This causes rigidity in the schedule, especially when the demanded times are incompatible with normal scheduling.

Table Eight: Stanford, Tokyo Idle Time ** (minutes)

	Stanford [s.d.]	Tokyo [s.d.]
Monday	54.75 [6.77]	52.50 [36.56]
Tuesday	57.38 [4.55]	28.17 [11.85]
Wednesday	52.01 [4.40]	46.49 [27.68]
Thursday	49.12 [3.06]	47.48 [27.77]
Friday	63.31 [6.26]	26.18 [8.88]

**Excluding time from the last patient of the day until the first patient the next morning.

Table Nine: Stanford, Tokyo Room Utilization

	Stanford % 24 hours (s.d.)	Tokyo % 24 hours (s.d.)
Monday	20.18 % (0.058)	25.49 % (0.061)
Tuesday	25.92 % (0.031)	24.95 % (0.047)
Wednesday	25.10 % (0.027)	24.24 % (0.067)
Thursday	25.15 % (0.033)	17.51 % (0.055)
Friday	21.02 % (0.048)	24.00 % (0.070)
Weekday Total	23.45 % (0.047)	23.28 % (0.066)

The utilization figures in Table Nine are based upon a 24-hour day, since no objective measure of hours of operation could be developed for purposes of comparison. Utilization figures are remarkably consistent across the two institutions, with both Stanford and Tokyo using their ORs on average 23% of the day on weekdays. Although Stanford has a slightly higher utilization rate, this difference is not significant ($p=.815$). Also interesting is the pattern over the days of the week. At Stanford, Monday and Friday show lower utilization, probably explained by the incidence of both official and personal holidays adjacent to weekends. In Japan, official holidays do not fall preferentially on Mondays and Fridays.

Findings and Implications

When case mixes are adjusted, the total in-room time at Tokyo is 142.8% of that at Stanford. The time differential is driven largely by operating time, accounting for 67% of the 62.4 minute difference in total in-room time. Furthermore, our data underestimate procedure-specific time differentials, since Stanford patients more often undergo multiple procedures per operative episode. That is, because nearly one-half of the Stanford patients undergo more than one procedure in a single operative session (compared with one-fourth of the Tokyo patients), the surgical time difference per procedure is greater than our analysis reveals.

Given that the operation time differential explains a large part of the total in-room time difference, the pre- and post-op differences become less important. For example, suppose that Tokyo's case-mix adjusted average pre-op and post-op times could be instantly reduced to Stanford levels, while maintaining the same average operation time as before. In this hypothetical scenario, Tokyo's total in-room time would decrease by only 10%. Operative times constitute the largest component of the overall difference in in-room times between Tokyo and Stanford because of their large contribution to the level of in-room time in both hospitals.

It may be the case that Tokyo's smaller recovery area contributes to the higher in-room time by increasing post-op time. With an adjusted differential of 9.0 minutes post-op time, relative to the total in-room time differential of 62.4 minutes, a nine-minute change in post-op time would decrease the case-mix adjusted differential by 14.4%.

One of Tokyo's strengths is its shorter idle time. On average, there are about 55 minutes of idle time between operations at Stanford, compared to only about 40 minutes at Tokyo. This is likely due to differences in the scheduling environments of the two institutions. Stanford's experience of more cancellations and more scheduling rigidity likely leads to greater idle time.

Conclusion

By comparing surgical time differentials at Stanford and Tokyo aggregated by both procedure and surgical department, we find that the average Tokyo total in-room time exceeds that at Stanford by nearly one hour per case. The major driving force behind the time differential appears to be the operation time, with pre-op and post-op times contributing 33% of the difference. Finding that case mix, staffing inputs, and scheduling are not the most significant causes of the time gap, we conclude that the difference in volume is due to lower room utilization rules and longer in-room times. The longer times could be due to practice-style differences, unobserved case-mix differences, or differences in teaching technique. Our data do not provide the opportunity to pinpoint specifically what the different practice patterns are. Future research at the level of procedure-specific case studies, however, should be aimed at exploring the detailed facts surrounding these differences.

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