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Duration of operation as a risk factor for surgical site infection: comparison of English and US data

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Summary T times are used to categorize surgical procedures into long and short durations. They constitute a part of the US National Nosocomial Infection Surveillance (NNIS) risk index that is widely used internationally in surveillance for surgical site infections (SSIs). The objective of this study was to compare the US NNIS T times with data collected in England. The Surgical Site Infection Surveillance Service in England holds data collected by 168 hospitals in 13 categories of surgical procedures between 1997 and 2002. The 75th percentile and corresponding T time were calculated from English data and compared with US times. Differences in rates of SSI above and below the T times were compared. Graphical methods were used to assess the cut points that exhibited an association with risk of SSI. The results show that English and US T times were the same for all surgical categories except coronary artery bypass graft and vascular surgery, where the English T time was 4 h. The 75th percentile time for hip hemiarthroplasties was 40 min less than for total hip replacements (THR). Although the incidence of SSI in THR was significantly higher in operations lasting for longer than the T time ($P < 0.05$), no association between risk of SSI and T times set at 1, 1.5 or 2 h was observed for hip hemiarthroplasties. In conclusion, operations lasting for longer than the T time were associated with a higher risk of SSI in most categories. In the hip prosthesis category, this association only applied to THR.

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Introduction

The Study on the Efficacy of Nosocomial Infection Control (SENIC) project (US Centers for Disease Control and Prevention) developed a simple four-variable risk index to predict the likelihood of a patient developing a surgical wound infection.[1] This risk index comprised an additive score of four risk factors: an operation that involved the abdomen, an operation lasting for longer than 2 h, an operation classified as either contaminated or dirty, and a patient with three or more underlying diagnoses at discharge.[1] The risk index was later modified and is now used to stratify rates of surgical site infection (SSI) by the National Nosocomial Infection Surveillance (NNIS) system in the USA.[2,3] It has also been widely adopted by other surveillance systems. The NNIS risk index combines three factors: an American Society of Anesthesiologists' (ASA) score of 3 or more (measuring the patient's state of health at the time of surgery), a wound class of contaminated or dirty, and an operation lasting for longer than T h, where T varies with the category of surgical procedure. The risk index is similar to that used in the SENIC study as it scores each operation by counting how many of these risk factors are present.

The duration of an operation is a measure of the length of exposure to potential contamination, but may also reflect the complexity of the procedure and surgical technique. It is defined as the time between skin incision and completion of skin closure. The 75th percentile of the duration of the operation is used to determine the cut point between operations of short and long duration.[2] The T time is the 75th percentile of the distribution of procedure duration, rounded to the nearest hour, and is calculated for each category of surgical procedure. This cut point for specific groups of procedures is more appropriate than the 2-h time period used in the SENIC risk index[1,2] as it accounts more accurately for differences in the usual time taken to perform different operative procedures.[4]

The Surgical Site Infection Surveillance Service (SSISS), previously called the Nosocomial Infection National Surveillance Scheme, was established in England in 1997 to enable hospitals to undertake surveillance of hospital-acquired infections and to compare their results with national aggregated data. The SSISS currently uses the risk index devised by the US NNIS system to stratify rates of SSI. However, more than a decade has elapsed since the T times developed by Culver *et al*. (1991) were published.[2] Changes in operative technique that have occurred during this time may mean that these T times are no longer applicable. In addition, the US T times may not be relevant to surgery performed in England.

This paper describes an analysis of data collected on surgical procedures in England. The 75th percentile of the duration of operation data contributed to SSISS was used to develop an English T time for 13 categories of surgical procedure. This was compared with the T time from the US NNIS system.[2,3] The English T times were then assessed for their impact on risk stratification and association with increased risk of SSI.

Methods

Data from October 1997 to September 2002 from 168 English hospitals participating in SSISS were collected and captured in an in-house database using scanning software (Formic™, Formic Ltd, Kingston-upon-Thames, UK). Participation in the scheme was voluntary and data were collected according to a standard protocol for a minimum of three months. Data collected included the category of surgical procedure (Table I) and the specific Office of Population Censuses and Surveys (OPCS)[5] operative procedure code, together with the three risk factors that comprise the US NNIS index: wound classification, ASA score and duration of operation in minutes. Active systematic surveillance was undertaken by participating hospitals to identify patients that developed an SSI during the inpatient stay that met the case definitions.

Since, in the English surveillance system, all coronary artery bypass graft (CABG) procedures are included in a single category, OPCS codes were used to subdivide CABGs into the 'chest only' and 'chest and donor site' categories used by the US NNIS. OPCS codes were also used to subdivide the hip prosthesis procedures into total hip and hemiarthroplasties (partial hip replacement), and vascular surgery into procedures performed on the aorta, the carotid artery, the femoral artery and other procedures.

Data on 105 863 operations were available for inclusion in the analysis. Operations where the duration of operation or relevant OPCS codes were missing were excluded (3016 operations). Data from 102 847 operations from 168 hospitals were included in the analysis.

English T times were obtained by calculating the 75th percentile of the duration of operation in minutes for each surgical category and rounding it to the nearest whole number of hours. Where the 75th percentile was on the half hour, it was

Table I Distribution of the duration of operation and number of surgical site infections (SSIs) in English data by category of surgical procedures

Category of surgical procedure	Number of operations	SSI	(% SSI)	Range of times (min)	Times at percentiles (min)		
					p25	p50	p75
Abdominal hysterectomy	8581	193	(2.2%)	17–500	52	66	90
Bile duct, liver, pancreas surgery	188	21	(11.2%)	35–600	141	200	240
Cholecystectomy	115	4	(3.5%)	20–375	60	90	140
CABG – chest and donor site	13 777	539	(3.9%)	35–980	160	195	235
CABG – chest only	985	34	(3.5%)	45–555	140	180	215
Gastric surgery	342	34	(9.9%)	15–515	60	107	200
Total hip replacement	28 431	652	(2.3%)	12–490	73	95	120
Hemiarthroplasty	9647	494	(5.1%)	12–459	45	60	80
Knee prosthesis	19 923	316	(1.6%)	11–300	70	90	110
Large bowel surgery	8965	814	(9.1%)	20–940	90	130	175
Limb amputation	1449	223	(15.4%)	10–230	32	55	79
Open reduction of long bone fracture	4330	184	(4.2%)	10–470	52	75	110
Small bowel surgery	1056	94	(8.9%)	10–525	65	105	160
Vascular – aorta	1557	85	(5.5%)	10–770	135	180	230
Vascular – carotid	855	2	(0.2%)	14–380	90	120	150
Vascular – femoral	2114	238	(11.3%)	10–995	115	160	219
Vascular – other	532	38	(7.1%)	25–800	105	155	210

CABG, coronary artery bypass graft.

rounded up to the nearest whole number of hours. This was the same method used to determine the US NNIS T times for data captured since 1987.[2]

Chi-square test was used to compare the rates of SSI between operations of long (greater than the T time) and short (less than or equal to the T time) duration using both the English and the US T times by surgical category.

The validity of the T time in denoting procedures at higher risk of SSI was tested for each category of surgical procedure by plotting the *P* value for the difference between rates of SSI for procedures above and below a cut point, with cut points set at 15-min intervals in the duration of the operation. Where the *P* value at a particular cut point is below 0.05, this indicates a significant difference in the rate of SSI between operations above and below the time. This difference may indicate that the rate of SSI above the cut point is either significantly higher than the rate of SSI below the cut point time or significantly lower. If there is no significant difference between rates of SSI above and below the T time for a particular category of procedures, this suggests that either this T time is not associated with SSI or there is insufficient power to detect an association. The latter is most likely to occur at very long or short durations where the number of operations is small.

Data analysis was performed using Stata Version 8.x. (StataCorp, College Station, TX, USA).

Results

Table I shows the number of procedures, rate of SSI and distributions in duration of operation. These were positively skewed for all categories.

Comparison between English and US T times

The duration of operation at the 75th percentile in the English data was different to the US 75th percentile time in all categories of surgical procedure. The 95% confidence intervals suggest that these differences were significant for all categories except for large bowel surgery. However, when the English 75th percentile time was converted into a T time by rounding the time to the nearest whole hour, the English and US T times (in hours) were the same for all surgical categories except CABG (chest and donor sites) and vascular surgery (Table II).

The segregation of vascular surgery into four groups of procedures showed considerable variation in 75th percentile time between different types of procedure (Table I). Procedures involving the aorta had a 75th percentile time that was 80 min longer than procedures on the carotid artery. Apart from carotid surgery (3 h), all groups had a T time of 4 h. These times compared with a US T time for vascular surgery of 3 h.

Table II Comparisons of English and US T times

Category of surgical procedure	English T times			US T times	
	p75	95% CI	T (h)	p75	T (h)
Abdominal hysterectomy	90	90–90	2	120	2
Bile duct, liver, pancreas surgery	240	230–260	4	224	4
Cholecystectomy	140	120–165	2	110	2
CABG – chest and donor site	235	235–240	4	276.6*	5
CABG – chest only	215	210–220	4	255*	4
Gastric surgery	200	180–215	3	152	3
Hip prothesis	113	112–115	2	130.8*	2
Knee prosthesis	110	110–111	2	121.8*	2
Large bowel surgery	175	175–180	3	180	3
Limb amputation	79	75–81	1	85	1
Open reduction of long bone fracture	110	105–110	2	130	2
Small bowel surgery	160	150–170	3	199	3
Vascular surgery	210	205–210	4	202	3

*p75 times, personal communication (J. Edwards and T.C. Horan).
CI, confidence intervals; CABG, coronary artery bypass graft.

The segregation of hip prostheses into total hip replacement and hemiarthroplasty procedures showed a difference of 40 min in the 75th percentile time for these two types of procedure, converting to T times of 2 and 1 h, respectively. Distributions of the duration of operation of the two procedures were also markedly different, with a shorter range of times for hemiarthroplasties (Table I).

Proportion of operations above the T time

In 14 categories of surgical procedures (Table I), the proportion of procedures with the duration of surgery above the English T time was between 8% and 25%. In three categories, a higher proportion of procedures were above the T time: gastric surgery (29%), cholecystectomy (31%) and limb amputation (39%). Moving the cut point can markedly affect the proportion, e.g. changing the T time for CABG (chest and donor sites) from 5 h to 4 h increases the percentage of operations above the cut point from 5% to 21%. However, if the T time of 2 h for hip prosthesis surgery was applied to hip hemiarthroplasty operations, only a very small proportion of operations (4%) would be above the T time. Rounding the 75th percentile of 80 min to 1 h resulted in almost half the hemiarthroplasty operations being above the cut point, whereas a T time of 1.5 h had a more acceptable proportion of operations (15%) above the cut point.

Relationship between T time and incidence of SSI

In total, 3965 SSIs (overall infection rate of 3.9 infections/100 operations) were reported to the SSISS during the five years. The percentage of operations that developed an SSI varied by category of procedure (Table I).

To evaluate whether T time was associated with risk of SSI, the incidence of SSI in operations with a duration greater than the T time was compared with the incidence of SSI in operations with a duration at or below the T time. The incidence of SSI was higher in procedures with durations above the T time in all categories except for hip prosthesis, and was significantly higher in abdominal hysterectomy, CABG, gastric surgery, knee prosthesis, large bowel surgery and vascular surgery. This difference was observed for both the English and the US T times. When hip prostheses were segregated into total hip replacement and hemiarthroplasty, the incidence of SSI in total hip replacements was also significantly higher for procedures with duration of operation greater than the T time (Figure 1). In hip hemiarthroplasty, the incidence of SSI was higher in procedures with a duration of 1.5 h, but the difference was not statistically significant. In vascular surgery, only procedures involving the femoral artery had a significantly higher incidence of SSI above the T time.

The association between risk of SSI and duration of operation is illustrated in Figure 2. In abdominal hysterectomy, there is an association between incidence of SSI and T time when the cut points for duration of operation are between 45 and 240 min. This is illustrated by a P value of less than 0.05 for the difference in incidence of SSI above and below these times (Figure 2a). In the hip prosthesis category, where both total and hip hemiarthroplasty were grouped together, there was an association between risk of SSI and operations of between 195 and 215 min. However, there was no association at the T time of 120 min for this category (Figure 2b). If separated into total hip and hip hemiarthroplasty procedures, there was only a significant association between risk of SSI and duration of operation at the T time for total hip replacements (Figure 2c). In hip hemiarthroplasties, no clear cut point was associated with a significant difference in risk of SSI. This suggests that the T time at either 1, 1.5 or 2 h is not a good indicator of risk of SSI in this category of procedures (Figure 2d).

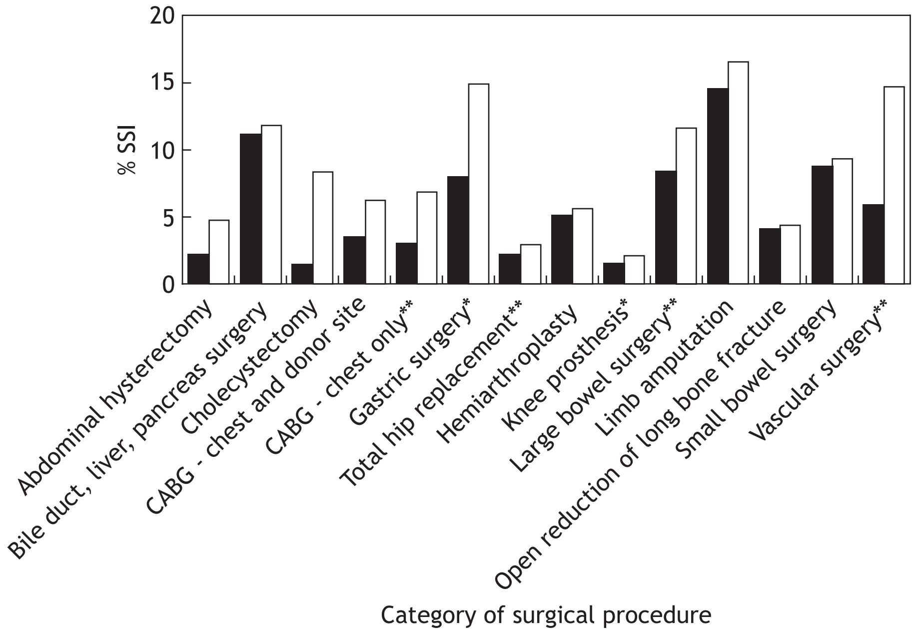

Figure 1 Risk of surgical site infection (SSI) in operations with durations above (open bars) and equal to or below (solid bars) the English T time by category of surgical procedure. *$P < 0.01$, **$P < 0.05$. CABG, coronary artery bypass graft.

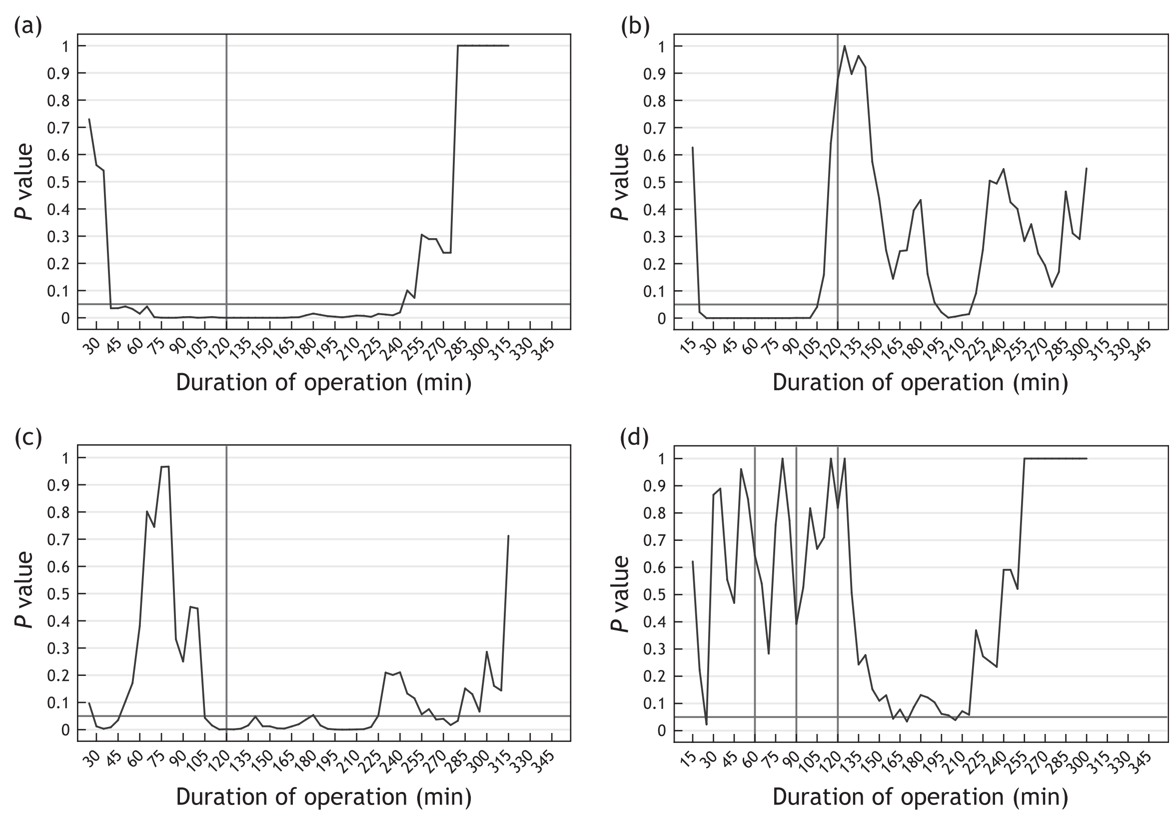

Figure 2 Association between *P* value and cut point for duration of operation for (a) abdominal hysterectomy procedures, (b) hip prosthesis procedures (both total hip and hemiarthroplasty), (c) total hip prosthesis procedures, and (d) hip hemiarthroplasty procedures. *X-line indicates both the US and English T times at 120 min (2 h) and the English T time at 60 min (1 h) and 90 min (1.5 h) for hip hemiarthroplasty procedures.

A significant difference in the incidence of SSI could indicate that the risk above the cut point is either higher or lower than the risk of SSI below the cut point. In the categories included in this analysis, the incidence of SSI was significantly higher above the cut point, except in the hip prosthesis category, where the rate of SSI was significantly lower above the cut point times between 15 and 105 min (Figure 2b).

Digit preference in recording the duration of operation was observed in all surgical categories. This occurs because the actual duration of the operation was rounded (up or down) to the nearest 5 or 10 min by the person recording the data. This effect is reflected by the small peaks or dips in association between risk of SSI and duration of operation that can be seen in Figure 2. The effect of digit preference is illustrated in Table III where the number of operations with a duration of operation at 120 min (T time for total hip prosthesis) is disproportionately greater than the neighbouring times.

Discussion

Extended duration of surgery has been identified as an independent risk factor for SSI by some studies, and may serve as a marker for the complexity of the individual case, some aspect of surgical technique, prolonged exposure to microorganisms in the operating environment, and diminished efficacy of antimicrobial prophylaxis.[2,6]

The duration of operation is a component of the US NNIS risk index, which is widely used internationally as a means of stratifying SSI surveillance data by risk. It has also been used to stratify data for the SSI surveillance scheme in England since the scheme commenced. Changes in the US 75th percentile times have been observed over the years, possibly due to changing operative techniques and case mix.[7–12] As a result, some alterations have been made to the NNIS T times. These include the separation of joint prosthesis into hip, knee and other prosthesis, and the separation of CABG into operations involving a chest incision only and those with incisions at both the chest and donor sites.[7] In 1997, the T time of the CABG (chest incision only) procedure decreased from 5 h to 4 h,[8] and in 2003, the T time for the limb amputation procedure increased from 1 h to 2 h.[11]

Campos *et al.* argued that since the length of operation may reflect not only factors intrinsic to the patient but also the influence of extrinsic factors surrounding the operation, a locally defined cut point may be a better predictor of the risk of SSI inherent in the local setting.[13] The disadvantage of this approach is that rates cannot be compared with those published by the Centers for Disease Control and Prevention and other institutions and countries using the standard NNIS T times.[4]

Since surgical techniques may vary between countries, some national surveillance systems have developed their own approach to determining a cut point for duration of operation. Some countries use a 75th percentile time in minutes derived from their own data as the cut point for stratification in the risk index instead of the NNIS T times.[14–16] However, it is important to consider the advantages of using a T time rather than a specific 75th percentile time. In particular, since the T time is rounded to the nearest hour, it provides a more stable indicator of procedures that are of unusually long duration.

It is also important to take account of the proportion of procedures denoted as being of unusually long duration by a particular cut point. In Brazil, surveillance data from a hospital collected over six years showed that the risk of SSI associated with operations of long duration was overestimated when the NNIS T time was applied.[13] Most of their surgical procedures had a longer duration of surgery, shown by their higher cut points when compared with the NNIS T times, which would imply that the proportion of infection above the NNIS T time would not be indicative of a long duration of surgery in Brazil.[13]

This large English dataset of operation times has provided an opportunity to evaluate the 75th percentile and T times compared with US data. The

Table III An example of digit preference in the allocation of duration of operation for total hip prosthesis

Time (min)	Number of operations
114	58
115	715
116	64
117	81
118	92
119	46
120*	1337
121	51
122	70
123	72
124	55
125	450
126	54

*Total hip prosthesis T time of 2 h (120 min).
Shaded rows indicate effect of digit preference.

analysis has shown that although there is a significant difference in 75th percentile time for most of the 13 categories of surgical procedures, this only affected the T time in two categories: CABG (chest and donor sites) and vascular surgery.

The 75th percentile time for CABG (chest and donor sites) procedures in England was 42 min less than the US time. While this may reflect differences in surgical technique between the two countries, it is also conceivable that the NNIS 75th percentile time derived in 1991 does not match current surgical practice in the USA. The difference in 75th percentile time between English and US data (235 min vs 277 min) reduced the English T time for CABG (chest and donor sites) procedures to 4 h from the US T time of 5 h. However, both of these T times were significantly associated with an increased risk of SSI. Using the English T time for CABG (chest and donor sites) resulted in 21% of operations being classified as of long duration as opposed to 4% with a T time of 5 h. Although this proportion may be considered more representative of operations of long duration, it is of note that the majority of CABG procedures performed in England involved a donor site (93%), and this may reflect underlying differences in case-mix or clinical management.

In vascular surgery, the English T time was 1 h longer than the US T time. However, subcategorization of these procedures suggests that the T time varies in different types of procedure, and the variation between the English and US T times may be explained by the frequency with which different types of procedure are performed. However, this analysis suggests that the current US T time of 3 h adequately discriminates operations at increased risk of SSI.

Hip hemiarthroplasty procedures account for about one-quarter of hip prosthesis procedures in England and have a cumulative rate of SSI detected in inpatients that is more than twice that of total hip procedures. The approach of the English SSISS has therefore been to separate the two procedures. The method of defining T time by rounding to the nearest whole hour presents difficulties when the duration of the operation is short. Rounding to the nearest whole hour would indicate a T time of 1 hour for hip hemiarthroplasties. However, for operations of such a short duration, rounding to a whole hour obscures the 75th percentile time and results in a T time that does not discriminate procedures of long duration. The English SSISS has chosen a T time of 1.5 h for hip hemiarthroplasty as this time designates a more reasonable proportion of the operations as being of long duration. However, the duration of operation does not seem to be a significant risk factor for SSI in hip hemiarthroplasties.

Digit preference is acknowledged as a problem associated with the measurement of continuous variables.[17] This analysis has shown the strong effect that digit preference has on recorded operation times, leading to a non-uniform distribution.[17] Since a T time will always represent a specific number of whole hours, digit preference will result in a proportion of operations with durations close to the T time being recorded with durations the same as the T time. However, since only those operations with duration above the T time are classified as being at greater risk of SSI, digit preference is likely to result in more operations being classified as less than the T time than is truly the case. The effect of digit preference on this analysis would therefore be to underestimate the true association between risk of SSI and operations lasting for longer than the T time. This is unlikely to introduce a large bias into the association and, as can be seen in Figure 2, the association between risk of SSI and duration of operation (or lack of it) is not crucial to the T time.

In conclusion, this analysis has demonstrated that despite differences in the 75th percentile times, the current US T times are the same as those calculated from English data in 11 out of 13 categories.

Whilst some countries have chosen to use local 75th percentile times as the cut-off point between procedures of high and low risk of SSI, this analysis supports the use of the T time as it reliably discriminates between procedures of low and high risk of SSI. In addition, it provides a more stable indicator of the cut point between operations of long and short duration, is less likely to be affected by small imprecisions in estimating the length of the operation or improvements in surgical techniques, and is less vulnerable to changes that would affect the comparability of historic data.

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