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Is It Time We Changed How We Measure Length of Stay for Hip and Knee Arthroplasty?

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Abstract

Introduction: Patient length of stay (LOS) for lower limb arthroplasty is a frequently quoted outcome measure. However, the use of mean values in days is prone to being skewed by outliers.

Methods: Between January 2013 and December 2015, patient LOS for primary hip and knee replacement was collected in 1,168 patients. There were two groups: pre- and postinstitution of the Rapid Recovery Program. The hypothesis was that reducing LOS would highlight proportionate differences when using hours as the measuring unit.

Results: Statistical analysis confirmed a significant reduction in LOS between the Enhanced Recovery Program and Rapid Recovery Program ($P < 0.001$).

Discussion: Use of the median LOS reduces the impact of outliers. Use of hours as the unit of measure of LOS enabled analysis of the time of day of discharge. With decreasing LOS and day-case arthroplasty, a measurement in median hours should become the standard to allow for the detection of subtle changes.

Reducing inpatient length of stay (LOS) for lower limb arthroplasty has been highly topical for some time, and mean LOS measured in days has become a frequently quoted outcome measure.

Utilization of enhanced recovery pathways has been shown to have several advantages, including LOS reduction,¹ decreased complication rates,² and improved 1-year patient-reported outcome scores.³ The potential for reductions in hospital costs while improving care is very promising.⁴

LOS is used for comparison between hospitals and surgeons. Analyzing and predicting trends in LOS has an important role in

healthcare planning and resource provision.

LOS has been defined as the duration of patient stay after admission to a ward.⁵ Because this is a discrete unit of measurement, LOS figures are rounded down to the complete number of days stayed within the hospital. Therefore, discharge on day 2 can be different from a 2-day LOS.

These figures are prone to inaccuracy because of several factors. First, LOS does not include a patient stay at rehabilitation units, which some authors suggest is frequent.⁶ By discharging patients to rehabilitation units, a false reduction in LOS can be achieved. The LOS for total hip

Table 1

Total Numbers of Patients per Procedure in Both Periods		
Procedure	No. of Patients per Procedure	
	January 2013–March 2015	April 2015–December 2015
THR	423	123
TKR	453	129
All patients	876	252

THR = total hip replacement, TKR = total knee replacement.

replacements (THR) has decreased from initially being approximately 3 weeks to 2 to 3 days.^{7,8} Therefore, the usage of days has become an increasingly blunt unit of measurement. Using a smaller unit of time, such as hours, has the ability not only to detect smaller changes in patient LOS but also to calculate when a patient is discharged. The usefulness of a patient discharge from a ward to facilitate admission of other elective patients varies with time of day. A patient being discharged 24 hours after a morning operation (ie, leaving the next morning) versus a patient being discharged 36 hours after the same morning operation (ie, leaving the next evening) may not seem significant on

paper but could assist the flow of patients through an elective ward. The morning discharge frees a bed for the following day’s operating list, but that isn’t true of the evening discharge.

Mean LOS is the most commonly utilized measure of centrality by healthcare organizations; however, it is prone to skewing the data because of small numbers of patients with long LOS. This is of particular relevance when comparing small volume data sets⁵; therefore, using the median LOS (when measured in days) reduces the impact of outlier patients. By taking this into account, drawing comparisons regarding LOS between different departments or surgeons is difficult. This is principally due to the hetero-

geneous nature of patient populations with variations in American Society of Anaesthesiologists (ASA) status, social support, and case complexity, as well as incorrect assumptions regarding data being normally distributed.

With the continued drive to decrease patient LOS, day-case lower limb arthroplasty has been achieved.⁹ It is now clear that LOS measured as a mean in days is no longer precise enough. The advantages of changing this to a median value measured in hours include a less ambiguous definition, with the patient episode commencing when the patient is admitted to a bed to when he or she is physically discharged. Highlighting causes for delay in discharge would be easier with a more precise measurement of discharge time.

The aims of this study were to observe the differences between the varying methods of measuring patient LOS regarding both the unit of time and also whether this was a median or a mean value. Second, we wanted to measure whether there was a difference in patient LOS before and after the initiation of the Rapid Recovery Program (RRP, Zimmer

Table 2

	Data Summary of Length of Stay					
	Pre-enhanced Recovery Group					
	THR		TKR		Overall	
	LOS (d)	LOS (h)	LOS (d)	LOS (h)	LOS (d)	LOS (h)
N	423		453		876	
Mean	4.1442	105.9007	4.4503	113.0773	4.3025	109.6119
SEM	0.15145	3.62262	0.19853	4.74701	0.12608	3.01504
Median	3.0000	82.0000	4.0000	99.0000	4.0000	94.0000
Mode	3.00	80.00	3.00	104.00	3.00	80.00
SD	3.11479	74.50621	4.22543	101.03443	3.73169	89.23714
Range	32.00	769.00	73.00	1,746.00	73.00	1,746.00
Minimum	1.00	23.00	0.00	9.00	0.00	9.00
Maximum	33.00	792.00	73.00	1,755.00	73.00	1,755.00

(continued)

LOS = length of stay, SD = standard deviation, SEM = standard error of the mean, THR = total hip replacement, TKR = total knee replacement.

Biomet) from the preceding Enhanced Recovery Program (ERP), the hypothesis of which was to demonstrate the increasingly blunt measure of LOS in units of 1 day.

Patients and Methods

This observational study was approved by the research and audit department within our hospital. A total of 1,128 patients were included in the study. In the first data series from January 2013 to March 2015, there were a total of 876 patients (the ERP group). Within the second data series from April 2015 to December 2015, there was a total of 252 patients (the RRP group). The breakdown of the various arthroplasty procedures performed within the two periods is shown in Table 1. All patients undergoing hip or knee arthroplasty were included, with no exclusions.

Patient LOS was captured electronically. The Trust's Business Intelligence System (Microsoft) software compiles data on LOS by recording the time of patients' electronic admission and discharge in hours. The patient cohort was checked to ensure that all coding for procedures was accurate and all incorrectly

coded patients were excluded (eg, the inclusion of patients with a THR for a fractured neck of femur was often coded as primary THR).

Data Recording

Patient LOS was recorded, in hours. Two separate data sets were created, first from January 2013 to March 2015 and then from April 2015 to December 2015. The separation is due to a change from ERP to RRP between the two dates, enabling a comparison between the two.

The early cohort underwent arthroplasty with standard ERP protocols. They were admitted the same day of surgery. The pain protocol consisted of intravenous paracetamol for the first 24 hours and oral paracetamol thereafter, ibuprofen (when no contraindications) TDS, and OxyContin BD, with OxyNorm (Mundipharma) for breakthrough pain and regular cyclizine as an antiemetic. On induction of anesthesia, patients received oral gabapentin, dexamethasone, and ranitidine. Varied anesthetic techniques were used (there was an even split between general anesthesia and spinal anesthesia).

They were mobilized at day 1 after surgery (not day 0). Knee replacements had surgery under tourniquet,

and a drain was used. No drains were used in hip replacements.

The second cohort had significant changes made to its protocols with the introduction of the RRP: They continued to be admitted the same day of surgery. The pain protocol was a fentanyl patch (low dose) 12.5 µg applied preoperatively. Intravenous paracetamol was administered for the first 24 hours and orally thereafter. Ibuprofen and regular cyclizine, as an antiemetic, were administered as previously described as well as OxyNorm for breakthrough pain. On induction of anesthesia, the patients were again administered oral gabapentin, dexamethasone, and ranitidine. There was an even split again between general anesthesia and spinal anesthesia. Early mobilization, preferably within 3 hours of surgery on day 0, was promoted both by physiotherapists and ward nurses.

Statistical Analyses

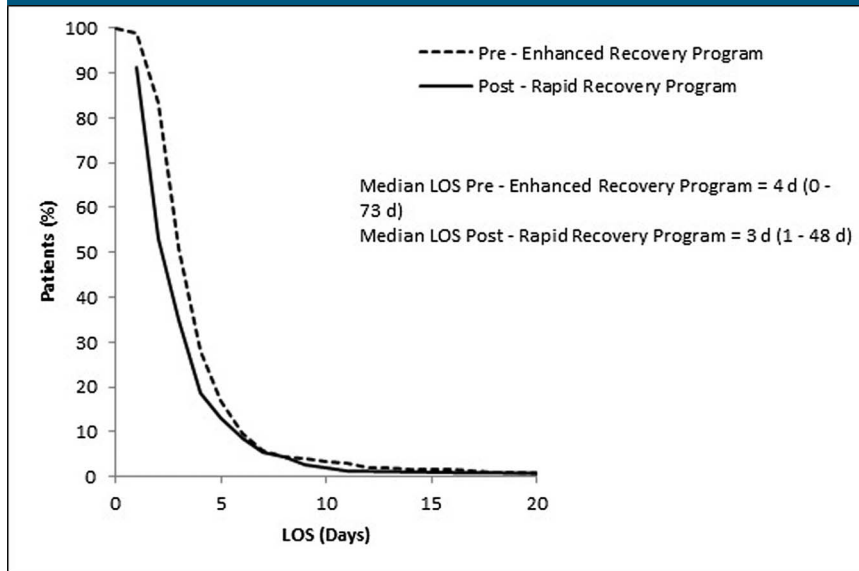
Analyses were completed using the Statistical Package for the Social Sciences (SPSS) version 21.0 (SPSS Inc.). Quantile-quantile plots were used to check the normality assumption of the dependent variables (LOS in days and

Table 2 (continued)

	Enhanced Recovery Group					
	THR		TKR		Overall	
	LOS (d)	LOS (h)	LOS (d)	LOS (h)	LOS (d)	LOS (h)
N	123		129		252	
Mean	3.0894	80.3415	4.1008	104.8992	3.6071	92.9127
SEM	0.19694	4.67782	0.45588	10.92339	0.25392	6.07786
Median	2.0000	57.0000	3.0000	80.0000	3.0000	73.0000
Mode	2.00	54.00	2.00	55.00	2.00	54.00
SD	2.18418	51.87956	5.17784	124.06581	4.03081	96.48302
Range	15.00	355.00	47.00	1,128.00	47.00	1,131.00
Minimum	1.00	25.00	1.00	28.00	1.00	25.00
Maximum	16.00	380.00	48.00	1,156.00	48.00	1,156.00

LOS = length of stay, SD = standard deviation, SEM = standard error of the mean, THR = total hip replacement, TKR = total knee replacement.

Figure 1



Kaplan-Meier curve for length of stay (LOS) within the two patient cohorts. LOS = length of stay.

hours) obtained for both RRP and ERP groups. Standard graphical methods were preferred over null hypothesis significance testing to check statistical assumptions.¹⁰ The normality assumption was not satisfied even after log transformation, and subsequently, data are reported as median (minimum–maximum), and nonparametric inferential statistics were performed.

Mann-Whitney *U* tests were used to examine the median difference in LOS in days and hours between ERP and RRP, and joint replacement (knee versus hip). In addition, the Kruskal-Wallis test was used to examine the median difference in LOS in days and hours between the recovery group (before and after enhanced recovery) and joint replacement (knee and hip).

Chi-square tests for association were utilized to examine the association between the time of discharge (0:00–11:59 [AM group], 12:00–16:59 [PM group], 17:00–23:59 [Evening group]) and LOS in hours (< 24, < 36, < 48 and > 48 hours), with ERP versus RRP, and type of joint replacement, that is, knee versus hip. Cramér *V* was

obtained to determine the strength of the association, with the following criteria applied: 0.00 to < 0.10, negligible association; 0.10 to < 0.20, weak association; 0.20 to < 0.40, moderate association; 0.40 to < 0.60, relatively strong association; 0.60 to < 0.80, strong association; 0.80 to 1.00, very strong association.¹¹

Finally, Kaplan-Meier curves were generated, and the log-rank test was used to determine whether there were differences in the distribution of LOS between the pre-enhanced recovery group and postenhanced recovery group. The two-tailed alpha level for significance testing was set at $P < 0.05$.

Results

Table 2 summarizes LOS in both days and hours. Measures of centrality, including median, mean, and mode, are included in Table 2. Comparing the LOS in the ERP versus RRP groups revealed a significant difference when measured in both days and hours ($U = 78,878$, $P < 0.001$; $U = 77,081$, $P < 0.001$,

respectively). Furthermore, there was a significant difference in LOS between knee and hip replacement when measured both in days and hours ($U = 139,499$, $P < 0.001$; $U = 139,009$, $P < 0.001$, respectively).

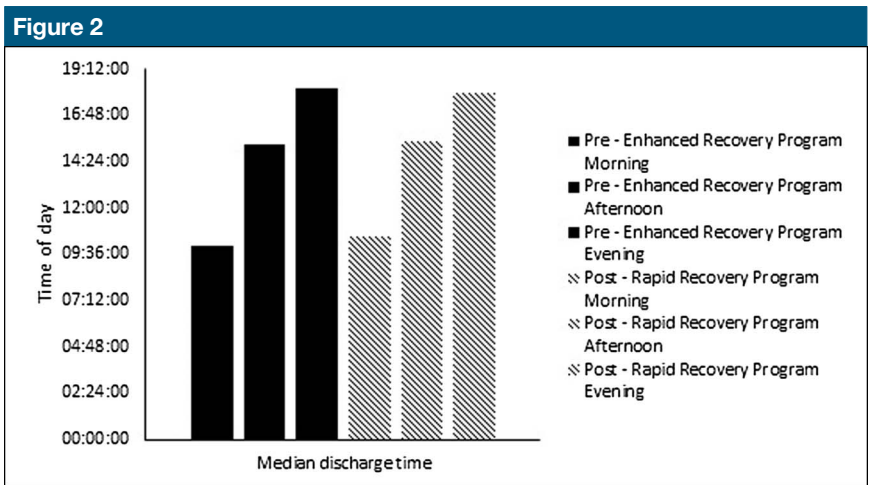
Figure 1 is a Kaplan-Meier survival curve displaying LOS in both cohorts and shows the decreased LOS within the RRP versus ERP group along with the range of LOS being narrower.

Analysis of the discharge time of day within the 2 cohorts showed that in the ERP group, 13% of patients were discharged between 00:00 and 11:59; 54% between 12:00 and 16:59; and 33% between 17:00 and 23:59. In the RRP group, 12% of patients were discharged between 00:00 and 11:59; 54% between 12:00 and 16:59; and 34% between 17:00 and 23:59. There was no association between recovery group (ERP or RRP) and time of discharge ($\chi^2 = 0.27$, $P = 0.87$, $\phi = 0.02$; negligible association). A Kruskal-Wallis test confirmed no significant difference in discharge time of day between ERP and RRP groups ($\chi^2 [2] = 1.78$, $P = 0.41$) for the knee or hip ($\chi^2 [2] = 0.31$, $P = 0.86$). This is illustrated in Figure 2 with roughly the same proportion of patients being discharged in the morning (therefore freeing up a bed for an afternoon case), afternoon, and evening (not freeing up a bed for the same day but reducing the nursing burden overnight and freeing a bed for a morning case) in both cohorts.

LOS in hours in the knee joint group showed that 0.2% of patients were discharged < 24 hours, 2.1% < 36 hours, 1.7% < 48 hours, and 96% > 48 hours after surgery. In the hip joint group, 0.4% patients were discharged < 24 hours, 2.7% < 36 hours, 0.5% < 48 hours, and 96.3% > 48 hours after surgery. There was no significant association between joint group (knee or hip when ERP

and RRP groups were pooled) and LOS in hours ($\chi^2 = 4.3, P = 0.23, \phi 0.2$; negligible association). Figure 3 shows that the spread of times for discharge narrowed after the RRP was introduced.

Figure 4 further subdivides the representation of time of day to show morning, afternoon, and evening discharge times, which enables the interpretation of whether the bed could be used productively the same day or the next day for another patient to undergo surgery.



Median discharge time relative to the time of day.

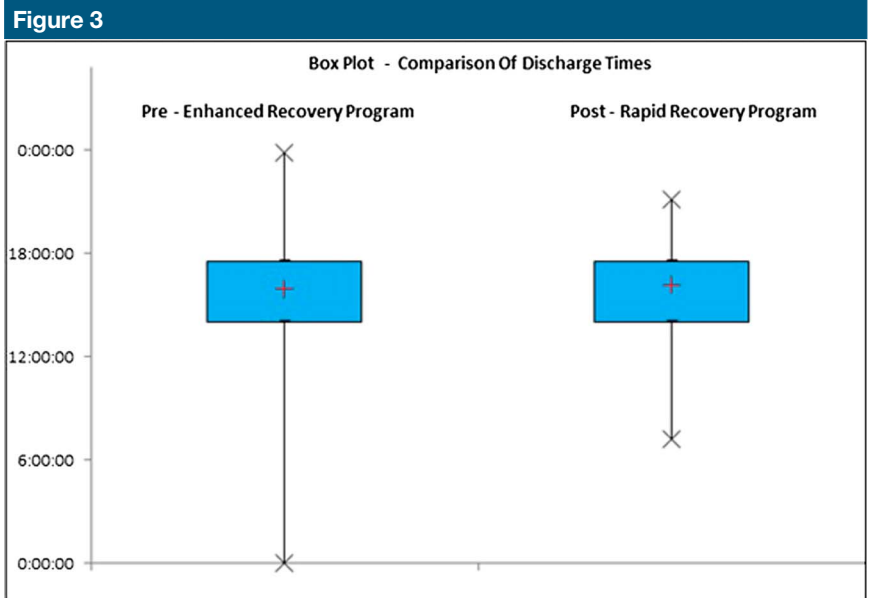
Discussion

Patient LOS has long been used as an outcome measure particularly involving lower limb arthroplasty.¹² With the introduction of enhanced and rapid recovery pathways, LOS is an increasingly quoted variable to detect clinical change.

The LOS for THR has decreased from initially being approximately 3 weeks to day-case surgery being a possibility.¹⁰ With the current surgical methods and rehabilitation pathways, day-case lower limb arthroplasty surgery is being considered.¹³ For this to be feasible, a structured approach must be used due to the multiple variables associated with patient LOS. Because patient LOS has already reduced significantly, an approach that incorporates the “aggregation of marginal gains” should be considered. A reduction in LOS by only a few hours has been shown to provide significant cost benefits.¹⁴

To approach this challenge systematically, the LOS data must not only be accurate and valid but also sensitive enough to detect a clinical change secondary to an intervention.

Regarding the unit of measurement for LOS, hours is a more sensitive unit of measurement for detecting an improvement. Auyong et al¹⁵ measured the LOS in hours needed for a significant effect, concluding that



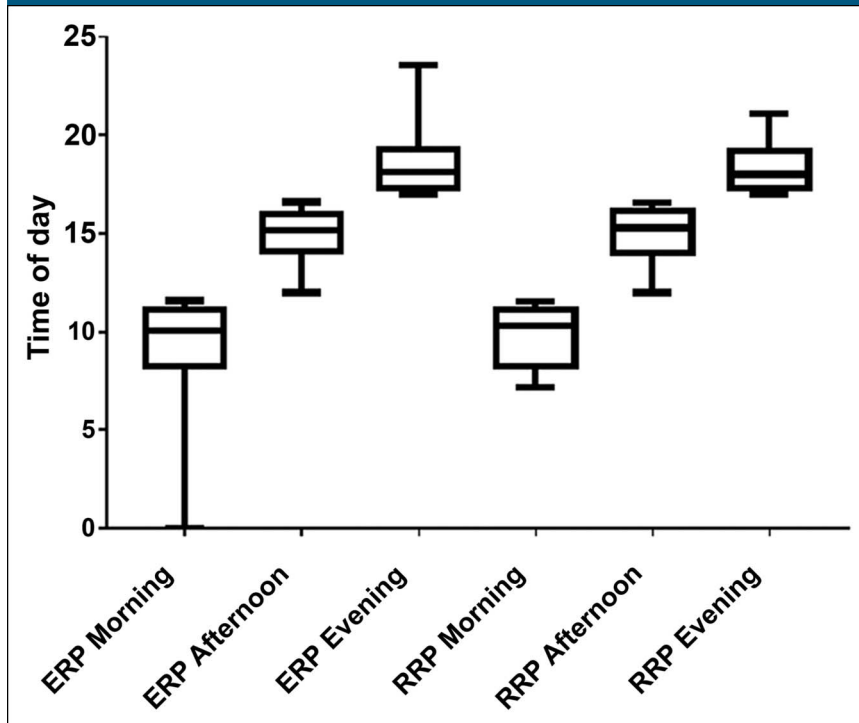
Box and whisker plot for overall discharge times for Enhanced Recovery Program versus Rapid Recovery Program).

they reduced LOS for total knee replacement by approximately 20 hours after implementation of a recovery pathway.

An evolutionary step of the LOS measure is bed occupancy measured in hours. From an economic perspective, patient LOS (when measured in days) fails to detect the effect of where the patients are during their stay. For example, two patients are admitted

for surgery on day 0 and both are discharged on day 2, with both being recorded as 2 days of LOS. Patient 1 was the first on the list and arrived at the postsurgical ward at 12:00; this patient was then discharged on day 2 at 22:00—an actual “Bed Occupancy LOS of 58 hours.” Patient 2 was the last on the list and arrived at the postsurgical ward at 18:00; this patient was then discharged on day 2

Figure 4



Box and whisker plot for discharge time divided up by morning, afternoon, or evening. For ERP versus RRP. ERP = Enhanced Recovery Program, RRP = Rapid Recovery Program.

at 08:00—an actual bed occupancy LOS of 38 hours, resulting in an actual bed occupancy LOS difference of 20 hours between the two patients. An awareness of bed occupancy in hours would assist in accurate costing and elicit further potential for improvement savings. By identifying the economics of patient stay more precisely, concepts such as bed hour cost and budgets could be more accurately estimated.

The timing of patient discharge is another important variable to optimize patient flow throughout a hospital. If a patient is discharged at 9 AM versus 2 PM, this 5-hour difference will have a much larger effect on patient flow compared with a patient being discharged at 4 PM versus 9 PM. Identifying patients who can be discharged at the optimal time and ensuring they are adequately managed for a timely

discharge will further assist bed capacity.

Using mean values in averaging LOS for groups of patients has limitations. A common example of this would be an “outlier” long-stay patient after limb arthroplasty with complex medical and social problems. Although in some institutions these patients may not be deemed appropriate for enhanced recovery pathways within our study, we have included all patients with primary arthroplasty, and therefore, this has raised the mean. Although the mean is the most commonly used measure of central tendency, it is prone to outliers, and this is even more apparent in small data sets. Using a median value prevents the distortion of outliers. (Median is preferable to mode values because it will produce only one figure rather than the potential of two with modes.)

Although mean values are more easily tested for statistical significance, this is not always appropriate. Within our data set, because the data were not normally distributed, it was not appropriate to use the mean and parametric tests.

We have shown in our study that the evolution from an ERP to a RRP was associated with a reduced LOS, from a median of 4 to 3 days for hips and knees, and from 93 to 73 hours. And further analysis of the LOS in categories such as the proportion discharged within 24, 36, 48, and greater than 48 hours revealed a greater proportion of patients going home in 36 hours or less in the RRP group. This is clearly good for bed usage in the orthopaedic ward.

However, the time of day at which the discharge took place did not change from ERP to RRP. This can be interpreted as a logistical or systematic issue that has not yet successfully been addressed. What is meant by logistical in this context is as follows.

Mobilization of patients is predominantly performed by physiotherapists and, to a lesser extent, the ward nurses. When the patient is deemed fit for discharge from the point of view of their safety on their feet, the ward doctor will be contacted to arrange their discharge. This involves writing their discharge summary and prescribing their discharge analgesia. There is often a delay from the request to the completion of the action, and the time of day at which this delay takes place (eg, afternoon or evening) can frequently result in an extra night’s stay in the hospital bed. The improvement in logistics to counter this would be protocolization of the discharge analgesia and adopting a system for prescribing these medications on the day of, or morning after, surgery so that they are ready when the patient is safe for discharge.

The timing of the postoperative radiograph can also result in a delay

for discharge, for example, in a busy hospital's radiography department. And the logistics improvement here would be an agreement with the radiography department to prioritize the (predictable number of) radiographs after surgery, either on the same day or the next morning. But as the LOS approaches day 1 (or 24 hours), the priority should become an agreement to radiograph the patient the same day of the surgery.

Use of drains in knee surgery entails the need to remove them the following day. While the drains are in the knee, they represent a restriction to mobilization due to their presence as a bottle to be carried with the patient as well as a source of discomfort within the knee itself during mobilization. In addition, the removal process itself takes time out of the ward nurse's working day, when they might otherwise be productively mobilizing patients.

Blood transfusions also take time to complete. Time often precludes mobilization by physiotherapists, with a secondary-effect increase in LOS. So the department's blood transfusion rate represents a measurable factor in the logistics of LOS. Improvements can be made by abolishing use of drains (which increase blood loss), use of tranexamic acid during surgery, and optimizing hemoglobin (Hb) levels before surgery.

These are all established examples of logistical steps relevant to LOS in patients with arthroplasty who contribute to both LOS and the time of day the patient is suitable for discharge (and hence at the time of day the bed is available for use for surgery). They

were not the focus of this article. But the analysis of the data showing no change in the time of day of discharge between ERP and RRP, despite a decrease in LOS in both hours and days, has highlighted that these are the next factors to tackle for LOS reduction and greater predictability of the time of day when beds become available for reuse for surgery.

In conclusion, implementation of an RRP within the general hospital setting resulted in a decreased patient LOS. The authors recommend that the measurement of LOS be in hours and recorded as a median value to increase sensitivity to change and to decrease outlier distortion. The timing of patient discharge is highly significant and should be considered when optimizing patient flow through an elective orthopedic ward.

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