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ORIGINAL ARTICLE

Centre volume and resource consumption in liver transplantation

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Abstract

Background: Using SRTR/UNOS data, it has previously been shown that increased liver transplant centre volume improves graft and patient survival. In the current era of health care reform and pay for performance, the effects of centre volume on quality, utilization and cost are unknown.

Methods: Using the UHC database (2009–2010), 63 liver transplant centres were identified that were organized into tertiles based on annual centre case volume and stratified by severity of illness (SOI). Utilization endpoints included hospital and intensive care unit (ICU) length of stay (LOS), cost and in-hospital mortality.

Results: In all, 5130 transplants were identified. Mortality was improved at high volume centres (HVC) vs. low volume centres (LVC), 2.9 vs. 3.4%, respectively. HVC had a lower median LOS than LVC (9 vs. 10 days, $P < 0.0001$), shorter median ICU stay than LVC and medium volume centres (MVC) (2 vs. 3 and 3 days, respectively, $P < 0.0001$) and lower direct costs than LVC and MVC ($90 946 vs. $98 055 and $101 014, respectively, $P < 0.0001$); this effect persisted when adjusted for severity of illness.

Conclusions: This UHC-based cohort shows that increased centre volume results in improved long-term post-liver transplant outcomes and more efficient use of hospital resources thereby lowering the cost. A better understanding of these mechanisms can lead to informed decisions and optimization of the pay for performance model in liver transplantation.

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Introduction

Liver transplantation remains a scarce resource with increasing demand, continued waiting list mortality and no increase in available organs.[1,2] Recent changes in organ allocation in the past decade, such as the introduction of the model of end-stage liver disease (MELD) score, have made strides at decreasing waiting list mortality and, in certain situations, decreasing waiting list times for transplant. However, this has come at a cost as this has resulted in an increased severity of patients typically being transplanted (i.e. higher MELD) and thus increased post-operative rates of complication and resource utilization.[3,4] The overall improvement in patient survival and transplant outcomes has come with a trade-off of significantly higher costs and questions about the cost-effective of liver transplantation.[5–7]

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With the advent of pending health care reform and pay for performance measures, the transplantation community can expect an increase in patient volume and declining reimbursement.[8,9] Public and private payers will be increasingly interested in cost-containment strategies and monitoring outcomes based on the cost-effectiveness of the procedure and the ability of the providers and their institutions providing the care.[7,10,11]

There has been significant work to optimize the liver transplantation allocation process. Many previous studies have studied the effects of MELD and donor characteristics, such as the donor risk index (DRI) on transplant outcomes such as length of stay (LOS), ICU utilization, patient/graft survival and cost.[3,6,12–16] To that end, the effect of the transplant centre volume on liver transplantation was published, demonstrating that higher volume centres were able to show increased patient and allograft survival with higher DRI organs.[17] Volume has been reported in the literature with varying effects on transplant outcome noted.[10,18–21] Given the

Table 1 Volume tertile case ranges, 2009–2010

Tertiles	Case range	Cases	Centres
2009			
Low volume centre	11–47	864	38
Medium volume centre	48–75	819	14
High volume centre	>76	942	11
	Totals	2625 cases	63 centres
2010			
Low volume centre	13–43	801	34
Medium volume centre	44–70	864	17
High volume centre	>71	840	11
	Totals	2505 cases	62 Centers

variability in the literature, a nationwide database that captures peri-operative cost data to evaluate volume effects was used.

As the health care industry experiences further cost-cutting measures and demands from external stakeholders to improve quality, it is imperative that work is undertaken to better understand what variables influence the cost of the care that is provided.

Methods

To develop this cohort, the UHC CDB/RM database was utilized to identify 63 transplant centres nationwide. Between 2009 and 2010, 5130 liver transplants were identified. This represents approximately 50% of the total liver transplants performed in the US during those 2 years when compared with available data from the Organ Procurement and Transplantation Network (OPTN).

Utilization endpoints included length of stay (LOS) and direct cost from the day of the transplant until discharge, ICU days and severity of illness (SOI). The SOI is an AHRQ-validated risk stratification tool that categorizes a patient as Minor, Moderate, Major or Extreme. UHC generates this value at the time of admission using a formulating incorporate the patients All Patient Refined Diagnosis Group (APR-DRG) Grouper and the contribution of their underlying comorbidities. Both LOS and direct costs were addressed from the day of transplant forward in order to account for prolonged pre-transplant hospitalizations that were variable across the cohort and to provide a more accurate analysis of a hospitals ability to care for the patient post-transplant. To address the potential differences in pre- and post-transplant phase costs, the total direct cost observed for transplant patient hospitalization was divided by the total LOS days to create an estimate of the direct cost per day.

We employed a similar technique as previously published to analyse transplant centre volume.[17] Transplant centres were ranked in order of annual case volumes by year. Transplant centres with fewer than five transplants per year were excluded. All observations were divided into tertiles and categorized into the following volume groups: High Volume Centres (HVC; upper one-third of observations), Middle Volume Centres (MVC; middle one-third of observations) and Low Volume Centres (LVC; lower one-third of observations). Because centre-specific procedure volumes varied from year to year, centre rank and subsequently tertile group designation were re-calculated for each year studied (See Table 1).[22,23]

Categorical values were expressed in percentages and tested using the χ^2 test. Continuous variables were expressed as means or medians and tested using non-parametric analyses. Statistical analyses were performed using JMP 9 Pro (SAS Institute, Cary, NC, USA).

UHC is an alliance of the nation's leading non-profit academic medical centres with 116 academic medical centres and 261 affiliated hospital members through its renowned programmes. UHC's membership includes more than 90% of the non-profit academic medical centres in the United States. The data within the UHC system are provided by the participating member medical centres. The data provided are demographic and ICD-9 diagnosis and procedure data. The member institutions provide charges for each patient encounter in the database. The charge data are then converted to a cost estimate using patient-level Medicare cost to charge ratios. UHC then employs Federally reported area wage indexes to normalize regional labour cost variation.

Results

In all, 5130 liver transplants from 63 academic transplant centres were analysed. The analysis was done first by comparing overall centre volume tertile characteristics and the distribution of patient severity types (Table 2), and then subsequently stratified by severity of illness (SOI). See Table 3 for a summary of the overall centre volume outcome measures and Table 4 for details regarding the univariate analysis of the cohort by SOI.

The in-hospital mortality between the volume tertiles demonstrated a significant improvement of 3.4% to 2.9% between low and high volume centres, respectively. When the centres were stratified by SOI, there was a significant improvement in mortality noted for HVC with extreme cases, 6.5% compared with 8.9% and 8.5% for MVC and LVC, respectively ($P < 0.0001$). It was noted

Table 2 Distribution of severity of illness patients between centre volume tertiles

Severity of illness	Centre volume tertiles		
	Low volume centre	Medium volume centre	High volume centre
Minor	133 (8.0%)	160 (9.5%)	143 (8.0%)
Moderate	650 (39.0%)	715 (42.5%)	719 (40.3%)
Major	564 (33.9%)	522 (31.0%)	551 (30.9%)
Extreme	318 (19.1%)	286 (17.0%)	369 (20.7%)

Table 3 Summary table of demographic and overall outcome measures by centre volume tertile

	Low volume centre	Medium volume centre	High volume centre	
Median age (range)	56 (18–78)	56 (18–75)	57 (18–81)	
Gender				
Males (per cent)	1 138 (32.8%)	1 153 (33.2%)	1 181 (34.0%)	
Females (per cent)	527 (31.7%)	530 (32.0%)	601 (36.3%)	
Race				
White (per cent)	1 151 (32.0%)	1 221 (34.0%)	1 223 (34.0%)	
Black (per cent)	165 (33.7%)	186 (38.0%)	138 (28.2%)	
Hispanic (per cent)	154 (37.7%)	95 (23.2%)	160 (39.1%)	
Asian (per cent)	71 (32.9%)	71 (32.9%)	74 (34.3%)	
Other (per cent)	124 (29.5%)	110 (26.1%)	187 (44.4%)	
				P-values
Mortality (%)	3.4	3.3	2.9	0.004*
Transplant to discharge length of stay (interquartile range)	10 (7–16)	10 (7–15)	9 (7–13)	<0.0001*
ICU length of stay (interquartile range)	3 (2–8)	3 (2–6)	2 (1–6)	<0.0001*
Direct cost of transplant to discharge length of stay (interquartile range)	98 055 (74 287–129 969)	101 014 (79 871–141 208)	90 946 (74 274–122 716)	<0.0001*

*$P < 0.05$ considered statistically significant.

that with major cases, LVC had a slight improvement in mortality, 2.3%, compared with HVC and MVC with 3.1% and 2.9%, respectively ($P = 0.017$).

Median overall LOS between high and low volume centres was noted to be 9 and 10, respectively ($P < 0.0001$). When separated by severity of illness, significant differences were found across all SOI categories with more profound differences between LVC and HVC for Major and Extreme cases. Specifically, Major cases saw a difference in LOS at LVC of 11 vs. 9 days at HVC ($P < 0.0001$) and Extreme cases were noted to have a LOS of 17 days at LVC and 13 days at HVC ($P < 0.0001$).

When looking at ICU utilization, measured in median days, there was a significant overall reduction for HVC, 2 days compared with 3 days for both MVC and LVC ($P < 0.0001$). When stratified by SOI, the effect persisted with decreasing ICU utilization from LVC to HVC's with the profound difference with Extreme cases, where there was a 3-day decrease in the ICU utilization at HVC as opposed to LVC.

The median direct cost of the inpatient admission from the time of transplant was significantly different between the three tertiles with median costs of $90 946 for HVC, $101 104 for MVC and $98 055 for LVC ($P < 0.0001$). When stratified by SOI, the cost differences varied slightly with significant direct cost improvements from LVC to HVC for Minor, Moderate and Major cases. There was a $14 700 improvement in the cost for Major cases at HVC vs. LVC. At the Extreme cases level, there was a greater than $10 000 difference in cost between HVC and LVC; however, the difference failed to reach significance.

Discussion

The results of the present study using the UHC Database have demonstrated a relationship between transplant centre volume and measurements of resource utilization in liver transplantation. As reported previously, centre volume has implications in the use of extended criteria livers and now seems to be a potential factor in the efficient use of hospital resources based on patient illness severity.[17] When discussing cost-effectiveness and resource utilization, it is always important to keep patient safety and survival as the priority before addressing issues surrounding cost. Interest-

Table 4 Univariate comparisons of variables stratified by volume tertiles

	Low volume centre	Medium volume centre	High volume centre	*P*-value
Mortality (%)				
Minor	1.2	0.0	0.7	0.021*
Moderate	2.6	1.5	1.3	<0.0001*
Major	2.3	2.9	3.1	0.017*
Extreme	8.5	8.9	6.5	<0.0001*
Transplant to discharge length of stay (interquartile range)				
Minor	8 (6–11)	8 (6–11)	8 (6–9)	0.0018*
Moderate	8 (7–12)	8 (7–11)	8 (6–11)	0.0104*
Major	11 (8–16)	10 (7–16)	9 (7–13)	<0.0001*
Extreme	17 (11–27)	16 (11–27)	13 (9–24)	<0.0001*
ICU length of stay (interquartile range)				
Minor	3 (1.5–4)	3 (2–4)	2 (1–3)	<0.0001*
Moderate	3 (2–4.3)	2 (1–4)	2 (1–4)	<0.0001*
Major	4 (2–8)	3 (2–6)	2 (1–5)	<0.0001*
Extreme	10 (4–20.3)	8 (4–15.3)	7 (3–17)	0.0145*
Direct cost of transplant to discharge length of stay (interquartile range)				
Minor	93 179 (74 957–120 840)	102 571 (81 145–152 057)	88 835 (72 530–118 457)	0.0274*
Moderate	93 369 (72 310–121 448)	103 770 (81 721–140 415)	90 624 (74 570–117 520)	<0.0001*
Major	102 399 (78 456–130 240)	95 325 (78 163–126 796)	87 693 (75 061–117 906)	<0.0001*
Extreme	110 851 (73 344–165 804)	105 817 (78 133–157 136)	98 960 (71 485–147 775)	0.1646

*$P < 0.05$ considered statistically significant.

ingly enough, the most impressive patient survival benefit we found occurred with the most extreme severity cases with HVC providing greater than a 2% improvement in mortality. With regards to utilization, HVC demonstrated significant efficiencies in care for the sickest of patients; however, this benefit appeared to wane for less severe patients. This correlates with previous findings that HVC have superior patient and graft survival when employing higher DRI allografts. Although we did not address MELD or DRI in this study, the UHC SOI score is an AHRQ risk-adjusted marker for patient severity and is calculated for each patient based on his or her diagnosis and/or procedure. Although not addressed here, a strong correlation was noted between the UHC SOI score and the MELD and it was felt it may be a good surrogate for MELD and patient risk stratification in the future. We plan to address this in future research.

An important aspect of this study was the evaluation of the cost post-transplant, in addition to the cost of the entire LOS. The correlation between higher volume and lower cost of care was stronger when analysed from the date of transplant to discharge. Pre-transplant LOS variability is likely difficult to address in the context of volume, as is resource overall resource utilization. It is hard to discern if a transplant centre's experience would portend higher quality and more cost-effective care pre-transplant as additional variables such as transplant region, waiting list status and diagnosis would likely cloud the picture. In this study, it is felt that the volume status of the centre is most critical around the immediate peri-operative timeframe through to the discharge of the patient. An additional area that will be considered in the future is readmission rates, particularly in the context of transplant-specific variables and centre volume. This is an important outcome measure that is important to consider in the context of LOS and cost savings. Peri-operative improvements in LOS, ICU utilization and cost may be negated by increases in readmission rates. In addition, taking into account the costs of readmission as well as any post-operative costs represents a more accurate representation of the total cost of a liver transplant.

As we highlighted earlier, donor and recipient variables are of critical importance to optimise patient and graft success post-transplant. The characterisation of recipient variables using MELD has been instrumental in making improvements to allocation algorithms and helping to boost transplant outcomes. The use of the DRI has been helpful in understanding donor variables and how they affect patient care, although this has not translated into the allocation system directly.[24] However, the new paradigms of health care reform and pay-for-performance threaten beneficial yet costly interventions.[8,9,14,15,25] In this study, the correlations between LOS and ICU utilization as markers for possible liver transplant quality and efficiency of care are highlighted. LOS has been described previously as a surrogate for resource utilization in liver transplantation.[26] Several previous studies have demonstrated that increasing MELD does result in increased cost and LOS, interestingly enough these same studies highlighted that hospitals that treated the highest MELD patients had a lower overall LOS indicating a possible learning curve.[14,27,28] Similar results where see in the present study and that hospitals seeing sicker patients, in this case as indicated by UHC severity of illness, were more efficient in taking care of these patients post-transplant. This effect appeared to reside with HVC, although we would want to correlate this effect with an analysis using the MELD and DRI scores and controlling for any differences in the distribution of more severe patients to certain hospitals and/or UNOS transplant regions. In addition, it would be interesting to see what types of patients were being transplanted at the LVC and MVC with regards to diagnosis, MELD exemptions and compare them in context to the pre-transplant LOS.

It is important to point out several limitations of this study. First, the UHC database is not a transplant database and contains administrative data pertaining only to the particular admission of interest. This may result in data entry errors and the database fails to capture approximately 50% of annual liver transplants performed. In addition, given the absence of roughly 50% of the US transplant centres, the true range of case volume is likely not represented in its entirety. For example, the max annual case volume reported by a centre in this study is 165 cases in spite of there being several centres not included in the UHC database that perform over 200 transplants per year. Second, the database only contains academic medical centre data. However, we feel that the majority of liver transplants only occur at academic medical centres. Third, the direct cost calculation in UHC utilizes Medicare cost–charge ratios as well as geographical labour–rate variations. It is based on hospital-reported charge data and may contain inherent flaws. However, given the consistent manner in which the database generates cost data, it is felt it is a strong database for comparing relative costs between institutions within the UHC system. Finally, we focused primarily on the post-transplant LOS both overall and for ICU utilization. That may have missed some critical information as it relates to the various volume centres. We plan to include data on the entire LOS in future work to ensure we address the entire admission as it relates to cost and resource utilization. Within UHC, it is difficult to identify when the patient entered the ICU and therefore to correlate it with the timing of the transplant. Work is ongoing in being able to identify this in the future to be sure that the post-transplant vs. overall admission ICU utilization can be framed accurately. There are likely a number of patients that were admitted to ICU before the transplant and required a tremendous amount of hospital resources prior to their transplant.

There are many potential reasons for the benefits seen at HVC, such as surgeon experience, transplant team experience and resource availability. Regardless, the results of this study require further investigation as they imply the possibility of being able to optimize health care resource utilization while potentially improving patient and graft survival. Although recommendations for changes to the allocation system to incorporate centre variables is out of the scope of this study, these data do suggest that there is value in assessing centres by their ability to optimally perform and manage certain types of transplants based on available allografts. We recognize that these data require validation and more detailed analysis; however, centre volume appears to play a large role in outcomes of liver transplantation.

The need for the field of surgery to develop definable and applicable measures of quality and safety are critical for patient referrals and reimbursement. Surrogate measures of health care outcomes have been debated in the literature and have been accused of painting an incomplete picture of the success of a given treatment or care modality.[29] Regardless, addressing liver transplantation both with regards to patient quality, safety and cost will be of the utmost importance if the modality is to remain a viable treatment option for patients.

Conflicts of interest

All authors have no disclosures or conflicts of interest to report.

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