Pediatr Transplantation 2008: 12: 174–179

Pediatric Transplantation
DOI: 10.1111/j.1399-3046.2007.00783.x

Financial implications of surgical complications in pediatric liver transplantation

Ammori JB, Pelletier SJ, Mathur A, Cohn J, Ads Y, Campbell DA, Magee JC, Englesbe MJ. Financial implications of surgical complications in pediatric liver transplantation.
Pediatr Transplantation 2008: 12: 174–179. © 2008 Blackwell Munksgaard

Abstract: Surgical complications following pediatric liver transplantation are common and expensive. We examined the incremental costs of surgical complications and determined who pays for these complications (center or payer). We reviewed the records of 36 pediatric liver transplant patients aged ≤ 12 yr transplanted between July 1, 2002 and December 31, 2005. The association of recipient and financial data points was assessed. On univariate analysis, total hospital costs were significantly increased in patients with ACR, PNF, HAT, biliary complications, and ARF. Reimbursement by the payer was significantly increased in patients with PNF, HAT, biliary complications, and ARF. Hospital profits were significantly decreased in recipients with ACR and pneumonia. Multiple linear regression models (controlling for recipient factors) revealed that ARF and HAT were independently associated with a significant increase in median hospital costs (incremental costs of $238 990 and $125 650, respectively). ARF and HAT were also independently associated with a significant increase in median reimbursements (incremental costs of $231 611 and $125 287, respectively). No complications were independently associated with hospital margins. All parties (patient and families, physician, payer, and medical center) should benefit from quality improvement efforts, with payers having the largest financial interest.

John B. Ammori, Shawn J. Pelletier, Amit Mathur, Joshua Cohn, Yasser Ads, Darrell A. Campbell, John C. Magee and Michael J. Englesbe

Department of Surgery, University of Michigan, Ann Arbor, MI, USA

Key words: quality improvement – transplant finances – complications

Michael J. Englesbe, Department of Surgery, University of Michigan, 1500 East Medical Center Drive, 2926 Taubman Center, Ann Arbor, MI 48109, USA
Tel.: (734) 936 8363
Fax: (734) 763 3187
E-mail: englesbe@med.umich.edu

Accepted for publication 29 June 2007

Pediatric liver transplantation has become the standard of care for children with end-stage liver disease. There are approximately 550 pediatric liver transplants performed annually in the USA (1). Approximately $154 million per year is spent on pediatric liver transplantations when factoring both the cost of the liver transplantation procedures and the maintenance of graft function and wellness of survivors (2). Although pediatric liver transplant patients represent only 0.004% of the total pediatric population, it is estimated that they account for 0.4% of the total pediatric health care expenditures (3). Complications following pediatric liver transplantation are relatively common, with early rejection, biliary complications, and early sepsis occurring in 25–40% of recipients (4). How these complications contribute to these health care expenditures is not described.

Our group recently proposed an infrastructure for QI in transplantation surgery with a specific focus on reducing surgical complications (5). Unfortunately, well-structured QI efforts are costly, require trained staff to collect and analyze the data. Additionally, these QI efforts add to the burden of mandatory clinical data reporting which already exists. A viable business model must be established for a national transplant surgical QI program considering the significant investment from both providers and payers.

Complications in pediatric liver transplantation are not only harmful to the patient, but also

Abbreviations: ACR, acute cellular rejection; ARF, acute renal failure; HAT, hepatic artery thrombosis; NSQIP, National Surgical Quality Improvement Program; PELD, pediatric end-stage liver disease; PNF, primary non-function; QI, quality improvement; SPLIT, studies of pediatric liver transplantation.

expensive for both the medical center and payer. With this paper, we attempt to quantify the expense of common post-operative pediatric liver transplant complications. Determining the financial stake holders in pediatric liver transplant complications is the first step in developing a comprehensive national QI program.

Patients and methods

Following Institutional Review Board approval, the electronic records for all pediatric (age ≤ 12 yr) recipients of liver transplants performed between July 1, 2002 and December 31, 2005 at the University of Michigan Health System were retrospectively evaluated. Data regarding donor, transplant, and recipient characteristics as well as graft and patient outcomes were obtained from both a prospectively collected database and review of the electronic medical record.

Several infectious and transplant-specific complications were evaluated. These included superficial skin infection, pneumonia, blood stream infections, peritonitis, urinary tract infections, other infections, ACR, PNF, HAT, biliary complications, and ARF. For the purposes of this study, we defined superficial skin infection as an operative site infection that required opening of the wound. Pneumonia, blood stream infections, urinary tract infections, and other infections were counted only if proven by a positive culture. *Clostridium difficile* colitis was diagnosed by typical symptoms and a positive toxin assay. Biliary complications were defined as detection of a leak or stricture in the intrahepatic or extrahepatic biliary tree on cholangiogram. HAT was diagnosed by doppler or ultrasound or upon operative exploration. PNF was defined as graft loss, retransplant, or patient death within 14 days of initial transplant not secondary to HAT, biliary complications, recurrent disease, or rejection. ARF was defined as post-transplant renal failure requiring renal replacement therapy in a patient who did not require pretrasplant renal replacement therapy. Analysis was limited to complications diagnosed within the first 90 days following the initial transplant event, including costs incurred secondary to retransplantation.

We obtained inpatient and outpatient financial data on physician procedural fees (surgeon, gastroenterologist, intensivist, interventional radiologist, and nephrologist), facility fees and reimbursements on each patient from the internal cost-accounting database at the University of Michigan. We collected financial data from the day of transplant (including the transplant operation) to 90 days post-transplant. We only account for costs of care within our health system. Organ acquisition costs and reimbursements were subtracted out of each patient's financial record and thus eliminated from the analysis. The TSI system (Transitions Systems, Inc., Shoreview, MN, USA) was used to identify total hospital costs (direct and indirect) and reimbursements. Reimbursements to the medical center were calculated based on a modeled revenue for reimbursements (constantly updated average for a payer based on hospital charges). The TSI system tracks the use of all resources and assigns estimates of cost based on direct acquisition costs for supplies and time-and-motion studies for labor costs. This method of activity-based cost accounting is widely believed to be the most accurate method of estimating the true economic cost of an episode of care (6). Hospital margins were calculated by the formula: hospitalreimbursements – hospitaltotalcosts.

The association of donor, transplant, recipient, and financial data points was assessed using both a nonparametric Mann–Whitney *U*-test for continuous variables and a chi-square analysis for categorical variables. We used a univariable and multivariable linear regression analysis to assess the effects of complications, donor characteristics, recipient characteristics, and payer (public or private). Because of small sample size, we restricted the multivariate models to compute the financial effect of each complication which was significant by univariable analysis. There was significant variation in the distribution of the financial data but the data was in a relatively normal distribution. As a result, we did not transform the dependant (financial) variables in the linear regression analysis. Statistical significance was accepted as $p < 0.05$ in the multivariable linear regression analyses. All statistical analyses were performed using STATVIEW version 5.0.1 (Abacus Concepts, Inc., Berkeley, CA, USA).

Results

The baseline donor and recipient characteristics of the 36 pediatric (age ≤ 12) liver transplant recipients between July 2002 and December 2005 are detailed in Table 1. Almost one-half of the patients required transplantation for liver failure secondary to biliary atresia with an average PELD score of nearly 21. Nearly one-half of the recipients had public insurance.

The one-yr survival of our cohort was 83.3% with six patient deaths all within the first 90 days. Four patients died within the first three-days post-transplant complicated by HAT. One patient who was transplanted because of hepatopulmonary syndrome died after a prolonged

Table 1. Donor and recipient characteristics (n = 36)

Donor	
Black (%)	5 (14)
Male (%)	21 (58)
Split liver graft (%)	7 (3)
Living donor liver graft (%)	1 (19)
Recipient	
Age (yr)	6 ± 4
Male (%)	16 (44)
White (%)	27 (75)
Diagnosis	
Biliary atresia (%)	17 (47)
Autoimmune hepatitis (%)	6 (17)
Fulminant hepatic failure (%)	5 (14)
Hepatoblastoma (%)	3 (8)
Other (%)	5 (14)
Preop dialysis (%)	2 (6)
LabPELD*	21 ± 8
Retransplant (%)	2 (6)
Liver cold ischemic time (min)	638 ± 218
Liver warm ischemic time (min)	43 ± 14
Public insurance (%)	17 (47)

*Calculated laboratory pediatric end-stage liver disease score.

hospital course highlighted by failure to wean from the ventilator, ACR, and CMV pneumonitis. The sixth patient had a relatively uncomplicated post-operative course prior to presenting to an outside hospital in extremis where he died. An autopsy to determine the cause of his death was not performed.

The number and percentage of specific complications is outlined in Table 2. Although limited by the small number of pediatric liver recipients and complications, univariable analysis was completed to assess the implications of individual complications on total hospital costs (Table 3). Higher costs were associated with ACR ($206 393 vs. $116 462; p = 0.07), PNF ($407 463 vs. $116 461; p = 0.1), HAT ($217 837 vs. $115 845; p = 0.01), biliary complications ($188 335 vs. $116 262; p = 0.06), and ARF ($440 376 vs. $116 262; p = 0.1). Public vs. commercial insurer did not affect total costs ($116 685 vs. $116 262, respectively; p = 0.69). Multivariable regression models individually assessing cost drivers which were significant with a p-value < 0.1 on univariate analysis while controlling for recipient characteristics (age, lab PELD, and public vs. commercial insurance) showed HAT and ARF as independent predictors of increased total hospital costs. HAT increased median total costs by $125 650 (p < 0.01) while ARF increased median total costs by $238 990 (p < 0.01).

Univariable analysis was completed to assess the financial implications of complications on insurer costs (hospital reimbursement) (Table 4). Higher reimbursements were associated with PNF ($332 034 vs. $126 029; p = 0.06), HAT ($230 006 vs. $119 424; p = 0.02), biliary complication ($214 679 vs. $121 755; p = 0.06), and ARF ($440 123 vs. $121 755; p = 0.01). Public vs. commercial insurer did not affect reimbursements ($170 984 vs. $152 012, respectively; p = 0.73). Multivariable regression models individually assessing the cost drivers to the insurer (reimbursements) which were significant with a p-value < 0.1 on univariate analysis while controlling for recipient characteristics (age, lab PELD, and public vs. commercial insurance) showed HAT and ARF as independent predictors of increased reimbursements. HAT increased median reimbursements by $125 287 (p < 0.01) while ARF increased median total costs by $231 611 (p < 0.01).

Univariable analysis was performed to assess the effects of complications on medical center profit (Table 5). Negative hospital margins were

Table 2. Post-operative complications (total n = 36 patients)

Complication	n (%)
Pneumonia	5 (14)
Urinary tract infection	3 (8)
Blood stream infection	7 (19)
Clostridium difficile colitis	5 (14)
Any infection	12 (33)
Acute cellular rejection	6 (17)
Primary non-function	2 (6)
Hepatic artery thrombosis	4 (11)
Biliary complication	3 (8)
Acute renal failure	3 (8)

Table 3. Total costs – univariate analysis values presented as median (interquartile range)

Complication	Yes	No	p-value
Acute renal failure	*$440 376 ($316 046)*	*$116 262 ($49 151)*	*0.007*
Primary non-function	*$407 463 ($522 539)*	*$116 461 ($60 535)*	*0.097*
Hepatic artery thrombosis	*$217 837 ($166 809)*	*$115 845 ($45 481)*	*0.001*
Acute cellular rejection	*$206 393 ($301 752)*	*$116 462 ($58 475)*	*0.075*
Biliary complication	*$188 335 ($393 764)*	*$116 262 ($58 838)*	*0.055*
Pneumonia	$188 315 ($375 838)	$116 662 ($54 852)	0.243
Urinary tract infection	$188 335 ($251 423)	$116 662 ($57 905)	0.587
Blood stream infection	$114 624 ($254 380)	$116 685 ($57 905)	0.704
Clostridium difficile colitis	$114 624 ($25 319)	$122 676 ($65 324)	0.450
Any infection	$113 179 ($73 760)	$124 181 ($59 570)	0.481

Table 4. Reimbursements by the payer – univariate analysis values presented as median (interquartile range)

Complication	Yes	No	p-value
Acute renal failure	*$440 123 ($193 499)*	*$121 755 ($55 637)*	*0.008*
Primary non-function	*$332 034 ($342 597)*	*$126 029 ($54 132)*	*0.062*
Hepatic artery thrombosis	*$230 006 ($158 592)*	*$119 424 ($57 087)*	*0.017*
Biliary complication	*$214 679 ($263 969)*	*$121 755 ($57 179)*	*0.055*
Acute cellular rejection	$216 801 ($209 962)	$126 029 ($54 132)	0.188
Pneumonia	$214 679 ($273 302)	$130 303 ($52 185)	0.372
Urinary tract infection	$214 679 ($193 096)	$130 303 ($54 840)	0.587
Blood stream infection	$153 483 ($200 273)	$130 303 ($54 840)	0.484
Any infection	$105 439 ($117 419)	$135 580 ($41 473)	0.365
Clostridium difficile colitis	$99 461 ($75 709)	$131 991 ($54 701)	0.325

Table 5. Provider profits values presented as median (interquartile range)

Complication	Yes	No	p-value
Acute cellular rejection	*−$16 014 ($97 511)*	*+$1756 ± ($32 464)*	*0.082*
Pneumonia	*−$12 280 ($112 193)*	*+$3765 ($32 648)*	*0.095*
Primary non-function	−$75 429 ($179 943)	−$487 ($34 563)	0.407
Blood stream infection	−$12 186 ($96 130)	−$253 ($31 898)	0.390
Any infection	−$11 406 ($46 850)	+$5046 ($27 609)	0.149
Urinary tract infection	−$10 626 ($86 054)	−$253 ($33 857)	0.510
Clostridium difficile colitis	−$2718 ($54 718)	−$253 ($33 136)	0.909
Acute renal failure	−$2,004 ($123,860)	+$3765 ($34 591)	0.264
Hepatic artery thrombosis	−$1129 ($20 131)	+$1522 ($34 102)	0.940
Biliary complication	+$7661 ($143 808)	−$721 ($33 857)	0.932

significantly associated with pneumonia (−$12 280 vs. +$3765; p = 0.01), and ACR (−$16 014 vs. +$1756; p = 0.08). Public insurance was associated with decreased hospital profit and a negative margin compared with recipients with commercial insurance (−$7396 vs. +$7661, respectively; p = 0.08). Multivariable regression models individually assessing drivers of hospital profit which were significant with a p-value < 0.1 on univariate analysis while controlling for recipient characteristics (age, lab PELD, and public vs. commercial insurance) revealed no statistically significant independent predictors of hospital profit. While both pneumonia and ACR were associated with >$20 000 negative hospital margin, this did not reach statistical significance (p = 0.11 and 0.08, respectively).

Discussion

We analyzed surgical complications following pediatric liver transplantation to build a financial argument for QI. Our results suggest that surgical complications are expensive for both the medical center and payer. Several complications such as HAT, ACR, ARF, pneumonia, and PNF of the transplant cost payers several hundred thousand dollars per episode. Presumably, some of these complications could not have been prevented. Nonetheless, it is important to consider strategies to reduce as many complications as possible. Such efforts could lead to substantial cost savings to medical centers, insurers, and society. Payers should take a particular interest in pediatric liver transplant QI as they bear the largest financial burden.

Hospital administrators and insurance providers are aware of the increased costs incurred by surgical complications. Median hospital costs were increased greater than sixfold in patients with a major surgical complication compared with those with no complications in one study (7). Reductions in post-operative pneumonias at the VA Hospital System have resulted in annual savings of $9.3 million (8, 9). Previous studies have also demonstrated increased cost of care associated with pediatric liver transplant complications. Recipients who developed surgical site infections, including organ and organ space infections, incurred a $132 507 increase in hospital charges compared with recipients who did not develop infections (10). Biliary complications have also been associated with increased costs (4, 11). In one study, HAT was associated with a $96 785 increase in the cost of the initial transplant hospitalization (12). Similarly, our study notes lower margins when patients had complications. Comprehensive efforts to improve the quality of care for pediatric liver transplant recipients will be expensive. Improvements in post-operative morbidity and mortality are noble goals in their own right, but a comprehensive QI program will need significant funding. Individual centers will likely financially benefit, if the pediatric liver transplant community can reduce complications. Unfortunately, their financial stake is quite small, considering the relatively small number of transplants performed annually even at the largest centers. Conversely, payers likely have a much larger financial stake in the pediatric liver transplant complications and are a potential partner in national QI efforts.

Pediatric liver transplantation may be uniquely suited to a comprehensive surgical QI effort. First, the community of pediatric liver transplant practitioners is small and relatively collaborative, making directed national QI efforts relatively easy. Secondly, data from the SPLIT registry has noted that there is remarkable variation in practice patterns among leading centers in the North America (13–15). While graft loss and patient mortality may be relatively insensitive to these variations, it may have profound effects on morbidity rates. Work from the NSQIP has repeatedly demonstrated that centers with similar mortality rates may have widely different morbidity rates (16–18). This variation in practice patterns lends itself well to comparative assessments of quality among centers. Finally, components of the infrastructure for a comprehensive QI program have been forged by the SPLIT. While the SPLIT consortium has made significant progress in defining the clinical practice of pediatric liver transplantation in its present form, it cannot serve as the ideal foundation for QI based on comparative evaluation of centers' practices and outcomes because it lacks rigid definitions of surgical complications, struggles with data collection, and has no focused infrastructure for QI.

It should be noted that any financial data is largely institution specific, and the use of our financial data for contract negotiations would be inappropriate. There are significant differences in cost-accounting methods between and even within medical centers on a year-to-year basis. Additional differences between institutions include personnel salaries, cost of living adjustments, indirect hospital costs, and contract rates of payment per organ. Furthermore, the analysis of public vs. commercial insurer reimbursements

is very specific to our center's payer mix and the contracts we have with private payers. The point of this analysis is that surgical complications drive the costs of the transplant event, and that the payers bear the burden of these costs. This general theme is likely applicable to a broad range of transplant centers in the USA, while the specific financial data should be assessed with caution. In addition, it is difficult to speculate how applicable the data and conclusions of this manuscript are to transplant care outside of the USA.

Our analysis is limited in scope for several reasons. First, it fails to quantify opportunity costs for the medical center, which generally runs at capacity. For example, having a pediatric liver transplant patient with a complication using a bed prevents another, potentially "profitable" patient from occupying that bed. Thus, the actual financial loss attributable to post-operative complications may be higher for the medical center. Secondly, we focus on the financial implications to the payer, the medical center and the providers, but not on the costs to the patient or society. Certainly a complicated post-liver transplant course will deleteriously affect a young patient's future health and productivity. Thirdly, the cost data is based on the University of Michigan Health Systems cost accounting methodology, and accounting assumptions are inherently imperfect and will have significant impact on data and associated conclusions. In addition, because this is a single center study of a relatively rare procedure, our patient sample size is limited.

In summary, pediatric liver transplantation, which has a relatively high complication rate, may be well suited to multicenter QI initiatives. A national QI program would provide an infrastructure to identify significant outliers for high quality with subsequent reporting of those centers' protocols and practices. Self-reporting of complication rates is inherently inadequate to determine who has the best practices in pediatric liver transplantation. As with NSQIP, these clinical outcomes should be collected prospectively by trained personnel using uniform definitions, and the data accuracy must be audited. These efforts would create a culture of QI and allow programs with outcomes inferior to their peers an opportunity to review the specific practices of high quality centers. This infrastructure will be expensive, and we suggest a national transplant QI program may be a sound investment for payers, offering promise for medical centers, payers and, most importantly, patients.

Acknowledgments

The authors thank to John C. Bucavalas for his editorial review and comments. MJE is supported by an American Surgical Foundation Grant. DAC is supported by a grant from the Blue Cross and Blue Shield Foundation.

References

1. Holsen S, Barr ML, Christensen LL, Ettenger R, Magee JC. Pediatric transplantation in the United States, 1996–2005. Am J Transplant 2007: 7: 1656–1660.
2. Bucuvalas JC, Ryckman FC. Long-term outcome after liver transplantation in children. Pediatr Transplant 2002: 6: 30–36.
3. United Network For Organ Sharing And The Division Of Transplantation Office Of Special Programs Health Resources Services Administration. Annual Report. Rockville, MD: US Department of Health and Human Services, 1999.
4. Cole CR, Bucuvalas JC, Hornung R, et al. Outcome after pediatric liver transplantation impact of living donor transplantation on cost. J Pediatr 2004: 144: 729–735.
5. Englesbe MJ, Pelletier SJ, Kheterpal S, O'Reilly M, Campbell DA Jr. A call for a national transplant surgical quality improvement program. Am J Transplant 2006: 6: 666–670.
6. Pronovost P, Angus DC. Cost reduction and quality improvement: It takes two to tango. Crit Care Med 2000: 28: 581–583.
7. Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA Jr. Hospital costs associated with surgical complications: A report from the private-sector National Surgical Quality Improvement Program. J Am Coll Surg 2004: 199: 531–537.
8. Arozullah AM, Henderson WG, Khuri SF, Daley J. Postoperative mortality and pulmonary complication rankings: How well do they correlate at the hospital level? Med Care 2003: 41: 979–991.
9. Arozullah AM, Khuri SF, Henderson WG, Daley J. Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery. Ann Intern Med 2001: 135: 847–857.
10. Hollenbeak CS, Alfrey EJ, Sheridan K, Burger TL, Dillon PW. Surgical site infections following pediatric liver transplantation: Risks and costs. Transpl Infect Dis 2003: 5: 72–78.
11. Englesbe MJ, Dimick J, Mathur A, et al. Who pays for biliary complications following liver transplant? A business case for quality improvement. Am J Transplant 2006: 6: 2978–2982.
12. Bucuvalas JC, Ryckman FC, Atherton H, Alonso MP, Balistreri WF, Kotagal U. Predictors of cost of liver transplantation in children: A single center study. J Pediatr 2001: 139: 66–74.
13. Mcdiarmid SV. Update from studies in pediatric liver transplantation. Transplant Proc 2001: 33: 3604–3605.
14. McDiarmid SV, Anand R. Studies of pediatric liver transplantation (SPLIT): A summary of the 2003 Annual Report. Clin Transpl 2003: 119–130.
15. Mcdiarmid SV, Anand R, Lindblad AS. Studies of pediatric liver transplantation: 2002 update. An overview of demographics, indications, timing, and immunosuppressive practices in pediatric liver transplantation in the United States and Canada. Pediatr Transplant 2004: 8: 284–294.
16. Fink AS, Campbell DA Jr, Mentzer RM Jr, et al. The National Surgical Quality Improvement Program in non-vet-

erans administration hospitals: Initial demonstration of feasibility. Ann Surg 2002: 236: 344–353 (discussion 353–344).
17. Khuri SF, Daley J, Henderson WG. The comparative assessment and improvement of quality of surgical care in the Department of Veterans Affairs. Arch Surg 2002: 137: 20–27.
18. Khuri SF, Henderson WG, Depalma RG, Mosca C, Healey NA, Kumbhani DJ. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. Ann Surg 2005: 242: 326–341 (discussion 341–323).