Hospital Cost of Complications Following Liver Resection

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Introduction

Liver resection carries a high economic cost, and despite improvements in perioperative care, postoperative morbidity remains high[1, 2]. Developments in the diagnosis and management of liver tumours has broadened indications for hepatic resection[1]. Improving perioperative outcomes, alongside increasing knowledge of liver anatomy and physiology has resulted in an increase in the complexity and extent of disease considered operable[3, 4]. Increasing complexity and extent of resection, including repeat and two-stage resections, carries an increase in the incidence and severity of complications, with typically more than 50% of patients experiencing complications, even in high volume centres[1, 2].

Complications following liver resection carry a substantial clinical and economic burden, and present an important target for interventions seeking to reduce healthcare expenditure. As the demand for healthcare grows, utilising limited resources in an era of mounting costs is becoming paramount in maintaining an effective and universally available healthcare system. Despite this, there is limited health economic data available on the topic of hepatic resection, and even less so quantifying the cost of complications.

Primary outcome: The relationship between the extent of liver resection, the incidence and severity of complications, and the ensuing costs.

Secondary outcomes:
1. To establish the sources of cost differentials between complicated and uncomplicated patients.
2. The impact of surgical technique on the incidence and severity of complications and associated costs.

Methods

Inclusion criteria: Adult patients undergoing elective or emergent hepatic resection between July 2010 and June 2017, based upon ICD-10 codes specific to liver resection.
Exclusion criteria: Patients undergoing a 'deroofing of liver cyst' and liver biopsies were excluded.
Definitions:
- '*Major' liver resection:* 4 or more liver segments resected, with less than 4 segments considered as 'minor' resections.
- *Complications:* any deviation from the normal postoperative course, guided by the European Perioperative Clinical Outcome (EPCO) definitions[5].
- *Readmission:* unplanned readmission within a 30-day follow-up period.
- *Mortality:* death occurring within 30 days of the index admission.

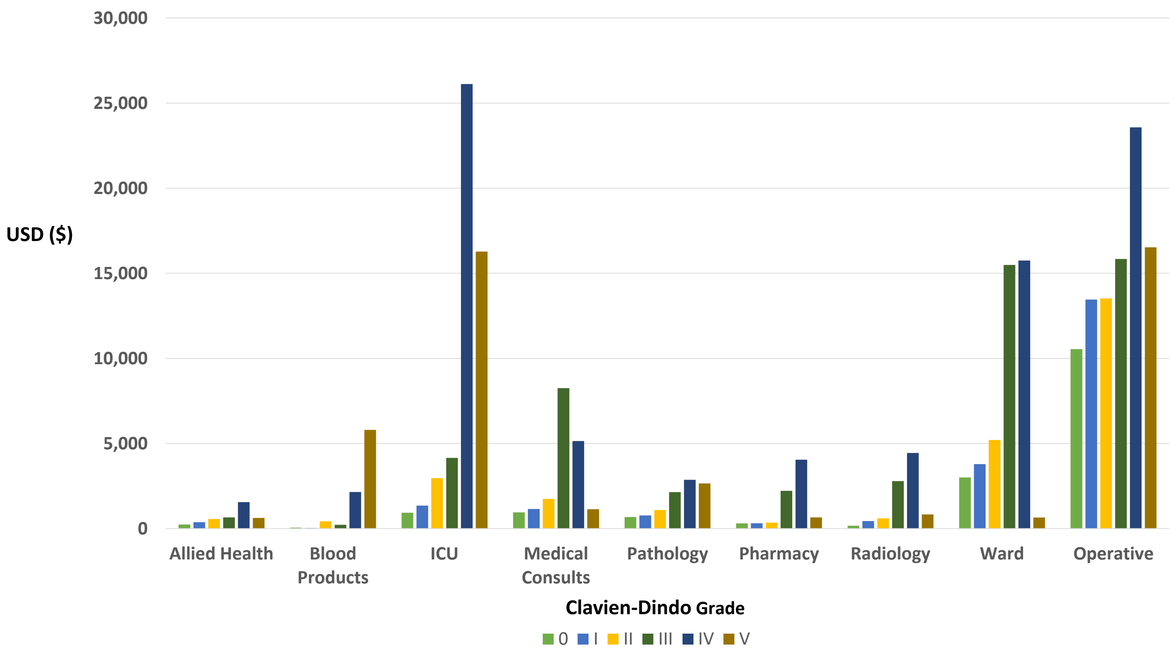
Complications: Graded according to Clavien-Dindo Classification[6]. The Clavien-Dindo classification is a validated approach to surgical outcome assessment that assigns severity grades to surgical complications.
Costs:
- All in-hospital costs related to the index admission and any consequent readmissions, including direct and indirect costs, were assessed to produce a total cost for each patient.
- Raw costing data was allocated into clinical cost centres including 'intensive care unit', 'medical' (e.g. medical consults, allied health, pathology, blood products, and radiology), 'operative', 'pharmacy', and 'ward' costs.
- Costs were inflated to 2018 dollars and conversion to United States Dollar (USD).

Cluster analysis:
- Using Kohonen's self organising maps we performed a cluster analysis to identify groups of patients with similar profiles of resource utilization.
- Cluster analysis was based on hospital resource usage of clinical cost centres (considered as a percentage of total cost).

Results

Patient characteristics:
- We identified 317 patients who underwent liver resection and met inclusion criteria.
- 66 (20%) patients had a 'major' liver resection and 251 (80%) had 'minor' resections.
- The median number of liver segments resected was 2 (IQR 1, 3).
- 89 (28%) patients had laparoscopic resections and 228 (72%) had open procedures

Figure 1: Hospital costs (2018 USD) by cost centre and severity of complications.



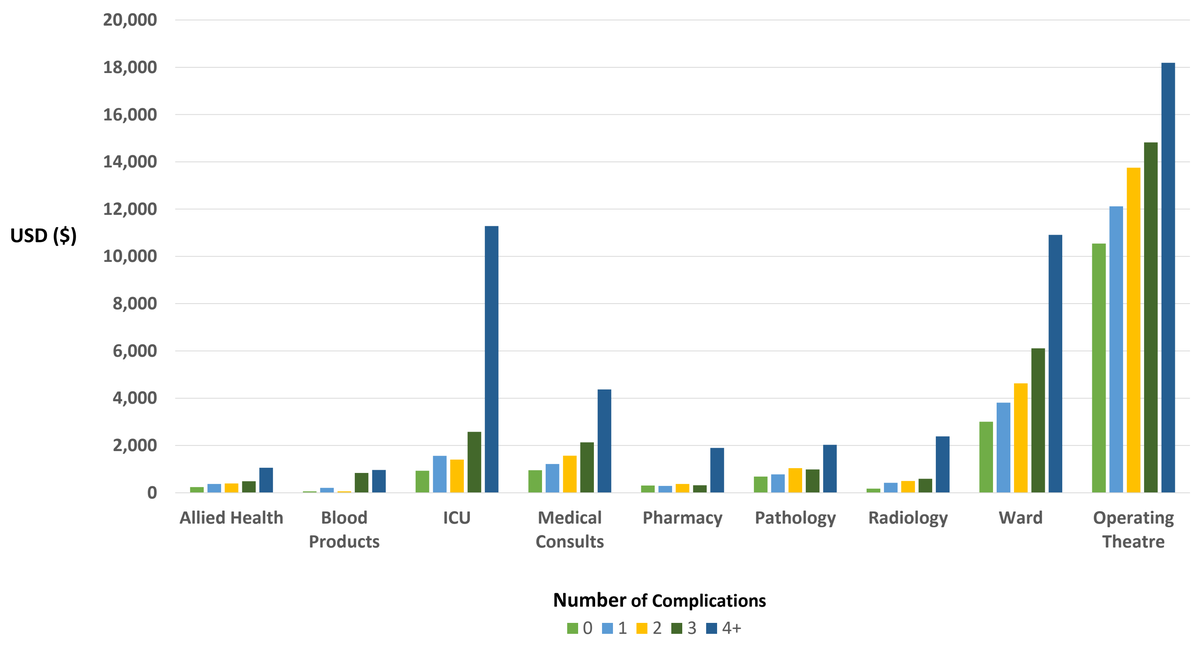
Complications:
- The overall complication rate was 64%.
- Complications were more common for open surgery compared with laparoscopy (72% vs 41.5%, p<0.001).
- Major complications (Clavien-Dindo Grade III-V) occurred in 10% of the cohort.
- Major resection was the greatest indicator of morbidity (82% vs 59%, p<0.001), and complication severity, with 21% of patients having a major complication, against 7% for minor resection (p<0.001).
- Nearly all major complications occurred in patients having open surgery (30 vs 2 complications, p<0.001).
- Patients experiencing a complication were older (62 vs 55 years, p<0.001) and sicker (CCI 7 vs 6, p=0.001).
- Mortality for the cohort was 0.6% (2 patients).

Table 1: Hospital costs (2018 USD) by cost centre.

	ICU	Medical	Pharmacy	Theatre	Ward	Total
No Complications	932 ± 1148	2104 ± 945	304 ± 474	12346 ± 6997	3240 ± 1261	**16884 ± 7501**
Complications	4339 ± 10306	5551 ± 7625	754 ± 3090	17042 ± 10209	6788 ± 8516	**31259 ± 30852**
p Value	<0.001	<0.001	<0.001	<0.001	<0.001	**<0.001**
Operative Technique						
Laparoscopic	484 ± 1288	2143 ± 1940	350 ± 633	12173 ± 6256	3299 ± 2799	**16599 ± 8258**
Open	4125 ± 9699	5143 ± 7195	685 ± 2906	16574 ± 10167	6361 ± 7962	**29731 ± 29372**
p Value	<0.001	<0.001	<0.001	<0.001	<0.001	**<0.001**
Segments Resected						
1	1972 ± 6837	3194 ± 3811	324 ± 491	12838 ± 6516	4460 ± 3271	**20421 ± 15056**
2	2401 ± 6544	3137 ± 2451	330 ± 226	14273 ± 7250	4152 ± 2453	**21941 ± 12031**
3	2104 ± 1320	3494 ± 1855	625 ± 1100	17204 ± 8157	4933 ± 2722	**25205 ± 9514**
4	5617 ± 11960	6464 ± 8507	1323 ± 5832	20331 ± 13958	8177 ± 11096	**38320 ± 43533**
5	7154 ± 8928	7637 ± 7601	845 ± 2047	22326 ± 14786	6083 ± 6103	**39892 ± 26018**
6	15750 ± 26624	27745 ± 24192	4585 ± 5961	27232 ± 9637	32582 ± 27092	**99653 ± 80435**
p Value	<0.001	<0.001	<0.001	<0.001	<0.001	**<0.001**
Extent of Resection						
Minor	2105 ± 6369	3203 ± 3274	355 ± 531	13756 ± 7018	4407 ± 2982	**21381 ± 13718**
Major	6898 ± 13014	8476 ± 11453	1488 ± 5295	21357 ± 14040	9664 ± 13594	**43780 ± 46346**
p Value	<0.001	<0.001	<0.001	<0.001	<0.001	**<0.001**

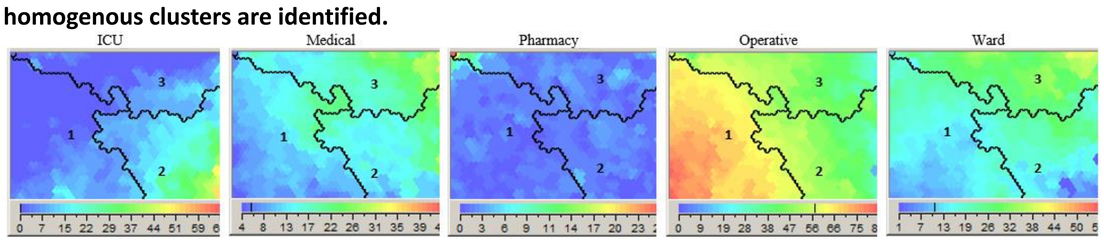
Cost analysis:
- Mean hospital costs for all patients were $26,044 (SD $24,955).
- Patients with complications cost $14,375 more than patients without complications (*Table 1*).
- Patients having open surgery cost nearly double compare to patients having laparoscopy *(Table 1).*
- Major resection cost more than double minor resection (*Table 1*).
- Costs increased by more than 50% between patients having 3 versus 4 segments resected (*Table 1*).
- Costs increased with both the incidence and severity of complications (*Figure 1 and 2).*
- Mortality corresponded with reduced total costs compared to patients with major complications.
- Patients with minor complications (grade I and II) cost almost $5,000 and $10,000 respectively more than uncomplicated patients.
- The majority of costs for all patients were attributable to operative (50%), ward (19%), ICU (12%), and medical consults (7%).
- Readmissions carried a hospital cost of $6,711 (SD $8,661).

Figure 2: Hospital costs (2018 USD) by cost centre and incidence of complications.



Cluster analysis:
- Cluster analysis identified three homogenous groups of patients based on the percentage of hospital cost attributable to each clinical cost centre, presented visually in *Figure 3*.
- Cluster 1 were the 'high-operative' usage group, cluster 2 were 'high-ICU' users, and cluster 3 were 'high-medical' users with high medical and ward costs.
- The high-medical users had the longest length of stay of all groups, and the most complications.
- The number of major complications was greatest for the high-ICU users (21%).

Figure 3: Mapping of patients by cost centre resource use as a percentage of total cost. Three homogenous clusters are identified.



Clusters are demarcated by the black lines. Each pixel represents a patient, plotted onto the map based on the proportion of hospital cost attributed to each cost centre. The colour of the pixel represents the percentage of total cost attributable to that cost centre for each patient, with a scale representing percentage of total cost included below each cluster map. Cluster 1 represents a high proportion of operative costs, Cluster 2 represents a high proportion of ICU costs, and Cluster 3 represents a high proportion of medical and ward costs.

Conclusion

Hospital cost and length of stay increased with greater severity and number of complications. The incidence and severity of complications increased with greater extent of resection and with open surgery. Our data provides strong evidence showing that both complications and costs significantly increase if four or more liver segments are resected, supporting previous findings[7].

Major complications placed an enormous burden on hospital resources, with grade III and IV complications costing three and five times respectively, more than patients without any complications. The majority of increased resource use for patients with major complications was due to large increases in the cost of ICU care, medical consults, and ward costs.

Additionally, we found a significant health cost associated with patients experiencing minor complications. The increased resource use for patients with minor complications included pathology and radiology, which provide a substantial target for cost containment through stewardship over blood tests and radiological investigations.

Minor complications may be preventable and they present the greatest target for reducing hospital resource use. As such, interventions targeting minor complications warrant further investigation.

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