ORIGINAL ARTICLE

ANZJSurg.com

Assessment of hospital characteristics associated with improved mortality following complex upper gastrointestinal cancer surgery in Queensland

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Key words
high-volume hospitals, hospital mortality, low-volume hospitals, oesophagectomy, pancreaticoduodenectomy.

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Accepted for publication 5 July 2019.

doi: 10.1111/ans.15389

Abstract

Background: High hospital-volume and service capability are associated with improved mortality following complex cancer surgery. Using a population-based study in Queensland, we assessed differences in mortality following oesophagectomy and pancreaticoduodenectomy, comparing high- and low-volume hospitals stratified by service capability.

Methods: Data on all patients undergoing oesophagectomy and pancreaticoduodenectomy for cancer in Queensland between 2001 and 2015 were obtained from the Queensland Oncology Repository. Hospital service capability was defined using the 2015 Australian Institute of Health and Welfare hospital peer groupings. Hospitals were grouped into 'high-volume (≥6 oesophagectomies or pancreaticoduodenectomies annually) with high service capability'; 'low-volume (<6) with high service capability' and 'low-volume with low service capability'. Multivariate Poisson models were used to estimate differences in 30- and 90-day mortality between hospital groups adjusting for age, sex, socioeconomic status, Charlson and American Society of Anesthesiologists scores, chemotherapy, radiotherapy, stage and time-period.

Results: For oesophagectomy, adjusted 90-day mortality was higher in low-volume compared with high-volume hospitals, regardless of service capability (low-volume, high service: incident rate ratio (IRR) 3.86, 95% confidence interval (CI) 1.74–8.57; low-volume, low service: IRR 3.40, 95% CI 1.16–10.00). For pancreaticoduodenectomy, mortality was higher in low-volume compared with high-volume centres regardless of service capability: 30-day mortality (low-volume, high service: IRR 2.32, 95% CI 1.07–5.03; low-volume, low service: IRR 3.92, 95% CI 1.45–10.61); 90-day mortality (low-volume, high service: IRR 2.36, 95% CI 1.29–4.30; low-volume, low service: IRR 3.32, 95% CI 1.64–6.71).

Conclusion: High hospital resection volumes are associated with lower post-operative mortality following oesophagectomy and pancreaticoduodenectomy regardless of hospital service capability. This data supports centralization of these procedures to high-volume centres.

Introduction

Oesophageal and pancreatic cancers are significant health problems and rank among the top 10 causes of cancer death worldwide.[1] In the main, surgical resection is the only curative treatment option for these malignancies, but is complex with 30-day mortality rates following oesophagectomy reported to range between 2.6% and 10%,[2–5] while for pancreaticoduodenectomy mortality ranges between 2.6% and 6.3%.[6–9]

In European and North-American population-level studies, significant improvements in post-operative mortality have been reported following oesophagectomy and pancreaticoduodenectomy performed in high-volume compared with low-volume centres;[10–14] and has led to the centralization of these procedures to high-volume hospitals in the UK, the Netherlands and Scandinavia.[15–18] By comparison, population-level studies in Australia have not reported improved post-operative mortality with higher hospital-volume following pancreaticoduodenectomy,[19] while for oesophagectomy, reports of improved mortality with higher surgical volumes are conflicting.[3,4,20] This may relate to lower resection volumes in Australian centres, including those considered ‘high-volume’, when compared with the volumes reported by centres in other countries,[10–14,19,21] and to the generally low mortality rates reported by Australian centres performing these procedures.[22] As well, some low-volume centres in Australia offer services including specialist surgeons, advanced endoscopy and interventional-radiology services which have been reported to be associated with lower post-operative mortality following complex upper gastrointestinal procedures such as pancreatic resection, independent of hospital resection volume.[23] It seems reasonable to consider this type of centre may significantly influence the volume–outcome relationship for oesophagectomy and pancreaticoduodenectomy in low resection volume regions, such as in Australia.

We hypothesize that, in the Australian environment, hospital service capability in addition to hospital-volume may influence post-operative mortality following oesophagectomy and pancreaticoduodenectomy. Using a population-level study of patients undergoing these procedures in the Australian state of Queensland, we aim to compare 30- and 90-day post-operative mortality between high- and low-volume hospitals stratified by their service capability.

Methods

Demographic, hospital and clinical data on all patients undergoing oesophagectomy and pancreaticoduodenectomy for cancer, in Queensland, between January 1, 2000 and December 31, 2015 were obtained from the Queensland Oncology Repository. This is a secure data repository containing cancer patient demographic, treatment and outcome data obtained from multiple administrative databases including the population-based Queensland Cancer Registry, the state death registry, public and private pathology, public and private hospital clinical data systems and Queensland Oncology On-Line.

Three age groups were constructed: 0–49 years; 50–74 years and 75 or more years and three time-periods were defined: 2001–2005; 2006–2010 and 2011–2015. Socioeconomic status was defined using the 2011 Index of Relative Socioeconomic Disadvantage[24] and patients were categorized into ‘Disadvantaged’, ‘Middle’ and ‘Affluent’ groups. Patient comorbidity scores were derived using Charlson[25] and American Society of Anesthesiologists (ASA) scoring systems with the scores dichotomized into Charlson ‘0’ and ‘1 or more’, ASA[1,2] ‘Normal or mild disease’ and ASA[3–6] ‘Severe disease’. Patients were considered to have received chemotherapy or radiotherapy as part of curative treatment if delivered within four and a half months of surgical resection. Treatment variables were categorized into surgery alone, neoadjuvant chemotherapy, neoadjuvant chemoradiotherapy, adjuvant chemotherapy and ‘other’ regimens. Cancer stage was manually collected for all patients from post-operative pathology reports and standardized to UICC Edition 7.[26]

A high-volume centre was defined as performing six or more oesophagectomies or pancreaticoduodenectomies annually within the three time-periods. These thresholds were chosen based on those reported in other Australian population-level studies[4,19] and health service publications,[27,28] as well as following an analysis of mean annual resection volumes within individual time-periods. Hospital service capability was defined using the 2015 Australian Institute of Health and Welfare Australian hospital peer groupings[29] with hospitals considered to have high service capability if classified as ‘Principle Referral Hospitals’ or ‘Private Group A hospitals’. Both these peer groups are defined by the presence of accredited intensive care units and specialized units such as neurosurgery and, in Queensland, would be able to provide interventional-radiology, advanced endoscopy and gastroenterology services. In addition, in Queensland, hospitals with a high service capability performing oesophagectomy or pancreaticoduodenectomy are staffed by surgeons holding post-graduate qualifications in upper gastrointestinal surgery. All other peer groups were defined as low service capability for the purposes of this study. No high-volume hospitals met low service capability criteria and hospitals were grouped into combined volume and service (VS) categories: high-volume, high service capability (HVHS); low-volume, low service capability (LVLS) and low-volume, high service capability (LVHS).

Crude 30- and 90-day death rates were calculated using the total number of deaths within 30 or 90 days, from any cause, following each procedure divided by the respective total number of oesophagectomies or pancreaticoduodenectomies performed in individual VS categories. For each procedure, demographic, tumour and treatment characteristics were compared between VS categories using chi-squared tests with significance set at a two-sided alpha of ≤ 0.05. Poisson regression models were used for multivariate analysis of 30- and 90-day mortality rates compared between VS categories. Directed acyclic graphs were used to select confounding variables and the models were adjusted for age-group, sex, socioeconomic status, Charlson and ASA scores, post-operative cancer stage, period and treatment variables. For both oesophagectomy and pancreaticoduodenectomy, patients with stage 0 and stage IV cancers were excluded from multivariate analysis as no deaths occurred in these groups. For pancreaticoduodenectomy, nearly all deaths occurred in patients receiving surgery alone and, for multivariate analysis of 30- and 90-day mortality, treatment variables were recategorized into ‘Surgery alone’ and ‘Other’ treatments. For similar reasons, for multivariate analysis of 90-day mortality for oesophagectomy, treatment variables were recategorized into ‘Surgery alone’, ‘Neoadjuvant chemoradiotherapy’ and ‘Other’. Results from the Poisson models are presented as incidence rate ratios (IRR) and model goodness-of-fit was assessed using deviance and Pearson’s statistics.

Ethical approval for this study was granted by the Metro South Health Human Research Ethics Committee (HREC/18/QPAH/303).

Results

In Queensland, between 2001 and 2015, 23 hospitals performed oesophagectomy and 25 hospitals performed pancreaticoduodenectomy. Over this period, for oesophagectomy, 1168 patients had surgery: 762 (65.2%) in five HVHS hospitals; 299 (25.6%) in 10 LVHS hospitals and 107 (9.2%) in 10 LVLS hospitals. Over the same period, 1043 patients underwent pancreaticoduodenectomy: 634 (60.8%) in four HVHS hospitals; 303 (29%) in 10 LVHS hospitals and 106 (10.2%) in 12 LVLS hospitals. Comparing the period 2001–2005 with the period 2011–2015, there was a small increase in the proportion of patients having oesophagectomy in HVHS (61.5% to 65.4%) and LVHS hospitals (24.6% to 27.3%) while the proportion having oesophagectomy halved in LVLS hospitals (13.9% to 7.2%). Comparing the same periods, the proportion of patients undergoing pancreaticoduodenectomy increased in HVHS hospitals (48.8% to 65.8%) and decreased in LVHS (34.2% to 27.4%) and LVLS hospitals (17% to 7.8%).

The demographic, clinical and treatment characteristics of patients undergoing oesophagectomy and pancreaticoduodenectomy compared between VS categories are shown in Table S1. For both procedures, there was no difference between VS categories with respect to patient sex, Charlson scores or post-operative stage. For oesophagectomy, a higher proportion of patients in HVHS hospitals lived in affluent areas, received neoadjuvant chemoradiotherapy and had ASA scores between three and six when compared to LVLS hospitals. For pancreaticoduodenectomy, a higher proportion of patients aged 75 years or more underwent surgery in LVLS compared with HVHS hospitals but HVHS hospitals had higher proportions of patients with ASA scores between three and six and higher proportions of patients receiving adjuvant chemotherapy.

Over the study period, the crude 30- and 90-day mortality rates following oesophagectomy were 0.94% (11 deaths) and 2.6% (30 deaths), respectively, while for pancreaticoduodenectomy, they were 3% (31 deaths) and 5.3% (55 deaths), respectively. Compared by time-period, for both procedures, the number of 30- and 90-day deaths were similar and there was no statistically significant difference in the rate of adjusted 30- or 90-day mortality (Tables 1,2).

After multivariate analysis of 30-day mortality following pancreaticoduodenectomy, mortality was higher in LVLS (IRR 3.92, 95% CI 1.45–10.61) and LVHS hospitals (IRR 2.32, 95% CI 1.07–5.03) when compared to HVHS hospitals. Similarly, adjusted 90-day mortality was also higher in LVLS (IRR 3.32, 95% CI 1.64–6.71) and LVHS (IRR 2.36, 95% CI 1.29–4.30) hospitals compared with HVHS hospitals (Table 1). Women had lower adjusted 30-day mortality when compared to men (IRR 0.36, 95% CI 0.16–0.82) and there is a suggestion of a lower rate of adjusted

Table 1 Post-operative mortality following pancreaticoduodenectomy in Queensland, 2001–2015

	Number of patients (%)	30-day mortality				90-day mortality			
		Number of deaths (%)†	IRR‡	95% CI	*P*-value	Number of deaths (%)†	IRR‡	95% CI	*P*-value
Combined volume and service capability									
High-volume, high service (HVHS)	628 (61.0%)	12 (1.9%)	1	—	—	21 (3.3%)	1	—	—
Low-volume, high service (LVHS)	299 (29.1%)	10 (3.3%)	2.32	1.07–5.03	0.03	19 (4.8%)	2.36	1.29–4.30	<0.01
Low-volume, low service (LVLS)	102 (9.9%)	9 (8.8%)	3.92	1.45–10.61	0.01	15 (14.7%)	3.32	1.64–6.71	<0.01
Age group									
<50 years	97 (9.4%)	2 (2%)	1	—	—	2 (2%)	1	—	—
50–74 years	787 (76.5%)	19 (2.4%)	1.19	0.28–4.96	0.81	40 (5%)	2.62	0.65–10.52	0.17
75+ years	145 (14.1%)	10 (6.7%)	1.46	0.33–6.47	0.61	13 (8.8%)	2.16	0.51–9.13	0.30
Sex									
Male	597 (58%)	24 (4%)	1	—	—	36 (6.0%)	1	—	—
Female	432 (42%)	7 (1.6%)	0.36	0.16–0.82	0.02	19 (4.4%)	0.67	0.39–1.16	0.16
Charlson score									
0	566 (55%)	11 (1.9%)	1	—	—	19 (3.3%)	1	—	—
1 or more	463 (45%)	20 (4.3%)	1.85	0.89–3.86	0.10	36 (7.8%)	2.00	1.15–3.47	0.01
Post-operative stage									
I	122 (11.9%)	2 (1.6%)	1	—	—	4 (3.3%)	1	—	—
II	588 (57.1%)	22 (3.7%)	3.42	0.86–13.60	0.08	31 (5.3%)	2.41	0.89–6.51	0.08
III	82 (8%)	3 (3.7%)	2.47	0.42–14.69	0.32	5 (6.1%)	2.27	0.63–8.17	0.21
Missing/cannot be assessed	237 (23%)	4 (1.7%)	1.01	0.20–5.23	0.98	15 (6.3%)	1.98	0.69–5.70	0.21
Socioeconomic status									
Disadvantaged	211 (20.2%)	7 (3.3%)	1	—	—	12 (5.7%)	1	—	—
Middle	673 (64.5%)	19 (2.8%)	1.32	0.60–2.91	0.49	32 (4.8%)	1.21	0.65–2.27	0.55
Affluent	159 (15.2%)	5 (3.1%)	1.55	0.52–4.60	0.43	11 (7.0%)	1.84	0.80–4.24	0.15
ASA score									
ASA 1–2	358 (34.3%)	9 (2.5%)	1	—	—	15 (4.2%)	1	—	—
ASA 3–6	446 (42.8%)	16 (3.6%)	1.28	0.57–2.87	0.54	27 (6.1%)	1.30	0.72–2.35	0.38
Unknown	239 (22.95)	6 (2.5%)	0.65	0.24–1.78	0.40	13 (5.5%)	0.83	0.41–1.69	0.61
Treatment									
Surgery alone	623 (59.8%)	30 (4.8%)	1	—	—	51 (8.3%)	1	—	—
Other§	414 (40.2%)	1 (0.2%)	0.05	0.01–0.37	<0.01	1 (0.24%)	0.13	0.05–0.37	<0.01
Period									
2001–2005	291 (28.3%)	12 (4.1%)	1	—	—	25 (8.6%)	1	—	—
2006–2010	325 (31.6%)	6 (1.8%)	0.77	0.26–2.29	0.64	10 (3.1%)	0.54	0.25–1.16	0.12
2011–2015	413 (40.1%)	13 (3.1%)	1.13	0.46–2.77	0.80	20 (4.8%)	0.73	0.39–1.37	0.33

†Row %. ‡Incident rate ratio (IRR) estimates from multivariate Poisson model regression analysis. §Other: Neoadjuvant chemotherapy, neoadjuvant chemoradiotherapy, adjuvant chemotherapy, neoadjuvant radiotherapy, adjuvant radiotherapy and perioperative chemotherapy.

90-day mortality in women compared to men. For patients with Charlson scores of '1 or more', 90-day mortality was higher when compared with patients with scores of '0' (IRR 2.00, 95% CI 1.15–3.47) and patients receiving chemotherapy or radiotherapy in addition to surgery had lower 90-day mortality compared with those receiving surgery alone (IRR 0.13, 95% CI 0.05–0.37). There was a non-significant trend to higher 30- and 90-day mortality with older age, higher cancer stage and ASA scores of 3–6 compared with scores of 1–2. There was no evidence of overdispersion within the models for 30-day (Pearson = 672.3, $P = 0.8$; Deviance = 144.5, $P = 1.0$) or 90-day mortality (Pearson = 579.3, $P = 1.0$; Deviance = 225.8, $P = 1.0$).

Analysis of 30-day mortality following oesophagectomy using multivariate models could not be performed due to the low number of deaths, with crude 30-day mortality rates of 0.1% (one death) in HVHS hospitals, 2.3% (seven deaths) in LVHS hospitals and 2.8% (three deaths) in LVLS hospitals. As with pancreaticoduodenectomy, the adjusted 90-day mortality following oesophagectomy was higher in LVLS (IRR 3.40, 95% CI 1.16–10.00) and LVHS (IRR 3.86, 95% CI 1.74–8.57) when compared with HVHS hospitals (Table 2). Adjusted 90-day mortality was also higher in patients with stage III cancer when compared to those with stage I (IRR 4.12, 95% CI 1.22–13.92) and there was a trend towards higher mortality with increasing patient age, in men, in patients with higher Charlson and ASA scores and in those receiving surgery alone. There was no evidence of overdispersion within the model following goodness-of-fit testing (Pearson = 745.9, $P = 1.0$; Deviance = 173.3, $P = 1.0$).

For both procedures, when the individual HVHS hospitals were compared there were no difference in the rates of crude 30-day mortality (pancreaticoduodenectomy: $P = 0.22$; oesophagectomy: $P = 0.64$) or 90-day mortality (pancreaticoduodenectomy: $P = 0.32$; oesophagectomy: $P = 0.95$).

Discussion

In Queensland, between 2001 and 2015, nearly 35% of oesophagectomies and 40% of pancreaticoduodenectomies were performed in low-volume hospitals with a quarter of these patients undergoing surgery in low-volume centres with low service capability. Despite generally low rates of post-operative mortality following these procedures over the study period, we have shown that adjusted 30-day mortality is significantly higher following pancreaticoduodenectomy in low-volume hospitals, regardless of their service capability, when compared with high-volume centres.

Table 2 Crude and adjusted 90-day mortality following oesophagectomy in Queensland, 2001–2015

	Number of patients (%)	Number of deaths (%)†	IRR‡	95% CI	*P*-value
Combined volume and service capability					
High-volume, high service (HVHS)	746 (65.4%)	12 (1.6%)	1	—	—
Low-volume, high service (LVHS)	290 (25.4%)	13 (4.5%)	3.86	1.74–8.57	<0.01
Low-volume, low service (LVLS)	105 (9.2%)	5 (4.8%)	3.40	1.16–10.00	0.03
Age group					
<50 years	110 (9.6%)	2 (1.8%)	1	—	—
50–74 years	892 (78.2%)	25 (2.8%)	2.22	0.53–9.39	0.27
75+years	139 (12.2%)	3 (2.2%)	1.02	0.20–5.47	0.98
Sex					
Male	939 (82.4%)	25 (2.7%)	1	—	—
Female	202 (17.6%)	5 (2.5%)	0.82	0.32–2.13	0.70
Charlson score					
0	675 (59.2%)	15 (2.2%)	1	—	—
1 or more	466 (40.8%)	15 (3.2%)	1.10	0.53–2.29	0.26
Post-operative stage					
I	282 (24.7%)	3 (1.1%)	1	—	—
II	213 (18.7%)	3 (1.4%)	1.03	0.21–4.98	0.97
III	377 (33.0%)	15 (4%)	4.12	1.22–13.92	0.02
Missing/cannot be assessed	269 (23.6%)	9 (3.3%)	3.16	0.89–11.25	0.08
Socioeconomic status					
Disadvantaged	243 (21.3%)	7 (2.9%)	1	—	—
Middle	710 (62.2%)	21 (3.0%)	1.10	0.47–2.56	0.83
Affluent	188 (16.5%)	2 (1.1%)	0.33	0.07–1.50	0.15
ASA score					
ASA 1–2	443 (38.8%)	8 (1.8%)	1	—	—
ASA 3–6	375 (33.9%)	12 (3.2%)	1.50	0.59–3.82	0.40
Unknown	323 (28.3%)	10 (3.1%)	1.30	0.53–3.19	0.57
Treatment					
Surgery alone	640 (56.1%)	18 (2.8%)	1	—	—
Neoadjuvant chemoradiotherapy	169 (14.8%)	8 (4.7%)	1.47	0.65–3.32	0.35
Other§	332 (29.1%)	4 (1.2%)	0.39	0.14–1.09	0.07
Period					
2001–2005	393 (34.4%)	14 (3.6%)	1	—	—
2006–2010	330 (28.9%)	5 (1.5%)	0.63	0.23–1.70	0.36
2011–2015	418 (36.6%)	11 (2.6%)	0.77	0.34–1.72	0.52

†Row %. ‡Incident rate ratio estimates from multivariate Poisson model regression analysis. §Other: Neoadjuvant chemotherapy, adjuvant chemotherapy, neoadjuvant radiotherapy, adjuvant radiotherapy, perioperative chemotherapy.

While the low number of deaths within 30 days following oesophagectomy precluded multivariate analysis, we demonstrated higher crude 30-day mortality rates in low-volume when compared to high-volume centres, and further demonstrated higher adjusted 90-day mortality rates following both oesophagectomy and pancreaticoduodenectomy with surgery in LVHS and LVLS hospitals when compared with high-volume centres.

Our findings are supported by reports of lower post-operative mortality following oesophagectomy and pancreaticoduodenectomy in high-volume compared with low-volume centres in several international population-level studies.[12,15–18,30,31] As well, a recent large Australasian study of 2000 patients undergoing oesophagectomy reported significantly lower rates of in-hospital mortality following surgery in high compared with low-volume hospitals;[20] however, this study did not include mortality outcomes from 'for-profit' private hospitals which are estimated to account for nearly one-third of all oesophageal resections in Australia.[4] In these studies, 'high-volume' hospitals are defined as performing between 12 and 34 or more oesophagectomies[10,20,31] and between 20 and 97 or more pancreaticoduodenectomies[13,31,32] annually. However, in Australia, few high-volume hospitals report similarly high resection volumes, despite reporting mortality rates comparable with those of international 'high-volume' centres.[21] Thus far, Australian population-level studies of oesophagectomy[4,33] and pancreaticoduodenectomy,[19] which use high-volume thresholds similar to those in our study, have not reported significant mortality differences between hospital-volume groups. This may relate to a lack of statistical power in these studies due to lower numbers of resections and a shorter time-period of assessment as compared with our study, low rates of post-operative mortality following these procedures reported in Australia[22] and the presence, in some low-volume centres, of hospital characteristics including high hospital technology, high-level intensive care, interventional-radiology services, and surgical training programmes which have been reported to be associated with improved post-operative mortality following upper gastrointestinal cancer surgery, independent of hospital-volume.[23,34]

To date, no population-level studies reporting post-operative mortality outcomes compared between hospitals, have adjusted for hospital service capability.[12,15–18,30,31] Our results suggest that, for hospitals with a high service capability performing oesophagectomy or pancreaticoduodenectomy, a resection volume of six or more procedures annually has a significant impact to improve post-operative mortality. In our environment, we have no evidence to suggest increasing threshold of high-volume to more than six resections would improve the post-operative mortality, given that mortality rates were similar among HVHS hospitals. This threshold may also be practical when considering centralization of these procedures in regions, similar to Queensland, with a large landmass, a small geographically dispersed population and where some regional hospitals offer a high service capability but lower resection volumes; and may broaden the pool of suitable hospitals which may help reduce travel distances for cancer care for rural and regional patients. However, the relationship between resection volume and surgical outcomes including post-operative morbidity, quality-of-treatment and long-term survival also need to be considered when defining high volume thresholds in the context of centralization.

Our study is limited by several factors including a lower number of resections and deaths compared with other published series,[15,16,18] which has resulted in wide confidence intervals around the IRRs for some comparisons. As well, pathological stage and data on ASA scores were not available for approximately 20% of the study population. We were also unable to identify patients undergoing treatment specifically for gastro-oesophageal junction cancers as data on the site around the gastro-oesophageal junction was not captured in the Queensland Oncology Repository. However, our results are relevant as many of these patients in our population will have had an oesophagectomy for this pathology.

Conclusion

In Queensland, post-operative mortality is lower following oesophagectomy and pancreaticoduodenectomy in high-volume centres, defined by performing six or more resections annually. For lower volumes of resection, the post-operative mortality is significantly worse, regardless of hospital service capability. This data offers further support for centralization of these procedures to what are considered high-volume centres in Australia.

Acknowledgements

The authors thank the Queensland Cancer Control Analysis Team; Research Assistants: Mr Brandon Leggett; Mr Callum Leggett; Mr Kevin Tian and Dr Theo Sklavos.

Conflicts of interest

None declared.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Demographic, clinical and treatment characteristics of patients undergoing oesophagectomy and pancreaticoduodenectomy in Queensland, 2001–2015.