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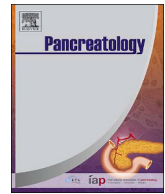
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Original Article

Aiming for high quality of care for completed resections and improved margin status in pancreatic cancer surgery



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ABSTRACT

Purpose: To assess associations between six diagnostic, staging, and coordination of care indicators in pancreatic cancer, and: (1) surgery being abandoned intraoperatively; or (2) a positive macroscopic margin (R2 resection) or a positive microscopic pathological margin (R1 resection).

Methods: Data was provided by the Upper Gastrointestinal Cancer Registry operating across two Australian states. Associations were tested using multivariable logistic regression.

Results: 704 patients underwent an attempted surgical resection (54 % male; median age 69 years). Of the completed resections (n = 585) with a known margin status (n = 513), 54 % (n = 278) were reported as having a negative pathological (R0) margin, 41 % (n = 211) had an R1 margin, and 5 % (n = 24) had an R2 margin. Patients who underwent surgery or neoadjuvant therapy within 60 days from referral had double the odds of a complete resection (OR=2.12, 95 % CI, 1.19 – 3.76). Imaging undertaken beyond 30 days prior to surgery had a 40 % reduction in the odds of a completed resection (OR=0.58, 95 % CI, 0.37 – 0.92). Patients with their ECOG and/or ASA documented at presentation had 90 % increased odds of a R0 margin resection (OR=1.90, 95 % CI, 1.32 – 2.73).

Conclusions: Timely progression to primary treatment had the most significant association with achieving complete resection status.

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1. Introduction

Pancreatic cancer (PC) is projected to become the second-leading cause of cancer death by the year 2030, and its clinical, societal and economic burden may double by 2060 [1–3]. Surgical resection of the primary tumour provides a possibility of cure but only 10–20 % of patients are diagnosed with resectable disease and undergo tumour resection with curative intent or longer-term

disease control [4,5]. Of those assessed as resectable, 10–30 % have surgery abandoned due to locally advanced or metastatic disease discovered intraoperatively [6–8]. PC surgery is often associated with significant post-operative morbidity, increased time spent in the hospital, and impaired quality of life [9]. In addition, the Australian mean hospital costs for uncomplicated PC surgery alone were an estimated \$25,000 to \$30,000 dollars (USD) in 2017 [10].

Surgical planning based on accurate imaging of the extent of the tumour is important to ensure the resection proceeds and to increase the likelihood of an R0 resection (≥ 1 mm clearance); i.e., complete tumour resection. However, the percentage of patients reported to have microscopic (R1) resection margins range between 28 and 71 % [11]. Margin status has important prognostic value, and it has been suggested that assessment of resectability should be based on the likelihood of an R0 resection, including an assessment of the tumour diameter and tumour abutment to the porto-mesenteric vessels on CT images to select patients with a higher possibility of margin-negative resections [12]. If an R0 outcome is unlikely, especially in borderline resectable, patients should be assessed for neoadjuvant chemotherapy followed by reassessment for suitability for surgery to achieve an R0 resection [8,13].

The implementation of a clinical pathway to minimise the risk of surgery needing to be abandoned or positive resection margins, is likely to reduce costs and resource utilisation while optimising patient-centred care and avoiding futile resection. We aimed to assess the association between six diagnostic, staging, and coordination of care indicators, that were identified using a modified Delphi consensus in an earlier study, and the outcomes of abandoned surgery or positive margins (R1 or R2 resection) [14].

2. Methods

We used data collected by the Upper Gastrointestinal Cancer Registry (UGICR) in New South Wales (NSW) and Victoria (VIC), Australia. Patients newly diagnosed with PC who met the eligibility criteria for the registry were recruited from multiple participating sites [15]. Patient, tumour and treatment characteristics have been routinely collected by the registry since its inception in 2015; an in-depth profile and details of the UGICR's design and ethics approval has been published elsewhere [15].

2.1. Study population

Patients from participating sites contributing to the UGICR, aged 18 years and over, with exocrine PC and who underwent an attempted resection between January 1, 2016 and 31 December 2020 from the states of NSW (population 8.2 million people) and VIC (population 6.7 million people) were included in this analysis. The definition of an attempted resection included all surgical procedures undertaken for the removal of PC. Exploratory laparotomies for resection were classified as 'abandoned surgery' if they were not converted to a resection.

2.2. Data collection

Trained data collectors extracted demographic, diagnosis and staging, surgical, pathology, and management data from the participants' electronic and/or hard-copy medical records from participating hospitals or from clinicians' private rooms. A short audit was performed for a subset of patients by two study authors (BB, HE) to collect additional information related to reasons for surgery being abandoned intraoperatively from 2016 to 2018.

2.3. Outcomes and quality indicators

The outcomes analysed were: (1) whether surgery was completed or abandoned intraoperatively; (2) margin status in those who underwent a complete resection, classified as clear (R0) versus microscopic (R1) or macroscopic (R2) following attempted resection. The quality indicators (QIs) examined were previously identified using a modified Delphi process [14]. This analysis was restricted to six indicators relating to diagnosis, staging, and coordination of care, that were deemed important for the surgical outcomes of interest. These were: (1) time from general practice (GP) or emergency department (ED) referral to primary treatment (surgery or neoadjuvant therapy); (2) documented pancreatic protocol CT (PPCT) scan for diagnosis and/or staging; (3) documented baseline CA19-9 before treatment; (4) documented performance status, Eastern Cooperative Oncology Group (ECOG) at presentation and/or American Society of Anaesthesiologist (ASA) classification at a diagnostic procedure; (5) disease management discussed at a MDT meeting; and (6) the MDT meeting was conducted prior to treatment.

2.4. Statistical analysis

Patient and tumour characteristics, and proportions of eligible patients (with 95 % confidence intervals) who met the diagnosis and staging indicators were analysed and reported. Compliance with QIs was calculated as the number of patients who met the indicator (numerator) divided by the number of patients who underwent surgery (denominator). In analyses of the QI, time from referral to primary treatment, we excluded those who had an unknown date of referral or treatment. Where there were missing data for relevant variables (e.g., because there were missing patient records), these were also excluded from the denominator [16]. Reasons for exclusion are provided in [Supplementary Table 1](#). Logistic regression (binary) was used to estimate the associations between the adverse surgical outcomes (abandoned resection, positive margins), and participant characteristics and compliance with the QIs. Associations between survival and abandoned surgery or positive margins were also estimated by the Cox proportional hazards model (the results for this analysis and discussion are provided in [supplementary material 2](#)). Variables considered as potential confounders of all analyses were identified based on clinical judgement and directed acyclic graphs. The potential confounders were retained in the model irrespective of whether they altered the effect estimates of interest. All analyses were undertaken using STATA 18.0 (StataCorp). A two-sided P value of <0.05 was considered statistically significant.

2.5. Ethical approval

This study was approved by the Monash University Human Research Ethics Committee (MUHREC #15325).

3. Results

The UGICR provided data on 2493 patients with PC from participating sites. After excluding those who did not undergo an attempted resection ($n=1760$), and 29 patients with incomplete resection details (e.g., missing type of surgical procedure), the final dataset included 704 patients with attempted resection for PC (28 %). Of these, 67 % ($n = 473$) were from NSW.

3.1. Patient characteristics

Demographic and tumour characteristics of included patients

($n=704$) are presented in Table 1. Of these, 28 % ($n = 194$) were treated with neo-adjuvant intent prior to surgery. The median age was 69 years (range 23–90 years) and 54 % were male. At diagnosis, in 30 %, documented resectability was unable to be clearly determined in the records (albeit that all these patients underwent an attempted resection). The majority of the tumours (77 %) were located in the head/uncinate process. Where dates for imaging were available at diagnosis or re-imaging following neoadjuvant therapy ($n = 570$), over 50 % ($n = 289$) were imaged using a CT or MRI scan within 30 days of surgery. Of the overall, 22 % ($n = 125/570$) were re-imaging data following neoadjuvant therapy. Seventeen percent ($n = 119/704$) had surgery abandoned intra-operatively. Of the completed resections ($n=585$), 72 patients (12 %) had incomplete data entry at the time of analysis for margin status. Therefore, for surgical margin outcomes that could be determined ($n=513$), 54 % of patients ($n = 278/513$) had a margin clearance ≥ 1 mm (R0 resection) or a clear margin status but with no distance specified and 46 % ($n = 235/513$) had a positive margin < 1 mm. Overall, the percentage of abandoned resections progressively increased according to the advancing classification of disease at diagnosis: 12 % ($n=31/251$) in those classified as resectable; 24 % ($n=33/140$) if classified as borderline resectable, and 39 % ($n=16/41$) in locally advanced disease.

3.2. Compliance with the quality indicators

Compliance with QIs are displayed in Table 2. Compliance was assessed overall, and according to margin or abandoned surgery. Two QIs had high overall compliance (>80 %). These were time from referral to primary treatment (surgery or neoadjuvant therapy) within 60 days ($n=446/526$, 85 %), and baseline CA19-9 assessed ($n=584/644$, 91 %). The percentage of patients who had primary treatment within 60 days was lower in those who had an abandoned resection ($n = 70/93$, 75 %) compared to overall. Approximately seventy percent of patients overall had their disease management discussed at a multidisciplinary team (MDT) meeting ($n=401/566$, 71 %), but lower compliance was noted in the positive margin group ($n=114/182$, 63 %). For 386 patients, we were able to derive dates for surgery and MDT meetings from the clinical notes and, of these, most patients were discussed prior to treatment ($n=349/386$, 90 %). There was less compliance overall with the assessment of tumour resectability using documented pancreatic protocol computed tomography (PPCT) ($n=315/577$, 55 %), and the documentation of Eastern Cooperative Oncology Group (ECOG) at presentation and/or ASA at a diagnostic procedure ($n=442/689$, 64 %) in those with an abandoned resection. Again, less compliance for documented performance status was noted in

Table 1
Patient and tumour characteristics.

Characteristic	Overall $n = 704$ (%)	
Age at diagnosis (years)	<55	94 (14)
	55–64	153 (23)
	65–74	265 (39)
	75–84	148 (22)
	>85	12 (2)
	Unknown ^a	32 -
Sex	Male	481 (54)
	Female	323 (46)
Eastern Cooperative Oncology Group (ECOG)	0	80 (12)
	1	49 (7)
	>2	16 (2)
	Not clearly documented ^b	536 (79)
	Missing	23 -
Resectability at diagnosis	Resectable	251 (41)
	Borderline resectable	140 (23)
	Locally advanced	41 (7)
	Not clearly documented ^b	184 (30)
	Unknown ^a	88 -
Site of Tumour	Head	460 (67)
	Neck	28 (4)
	Body	83 (12)
	Tail	55 (8)
	Uncinate process	38 (6)
	Pancreas (not otherwise specified)	26 (4)
	Missing	14 -
Imaging at diagnosis or following neoadjuvant therapy (no. of days prior to surgery)	≤ 30 days	289 (51)
	>30 days	281 (49)
	Unknown ^a	134 -
Surgery Completion	Surgery completed	585 (83)
	Surgery abandoned	119 (17)
Surgical Procedure^c	Pancreatico-duodenectomy (PD)	396 (68)
	Pylorus-preserving PD	26 (4)
	Distal pancreatectomy	99 (17)
	Total pancreatectomy	41 (7)
	Subtotal pancreatectomy	22 (4)
	Central pancreatectomy	1 (0.2)
	Margins reported as R0 or clear	278 (54)
	Microscopic margin (R1)	211 (41)
Macroscopic margin (R2)	24 (5)	
Missing	72 -	

Missing: incomplete data entry at the time of analysis.

^a **Unknown:** where full diagnosis or patient information is unable to be captured as patient may have records at non-participating sites, interstate or overseas.

^b **Not clearly documented:** where data collectors have perused the clinical records and found variables unclear or not clearly documented; e.g. resectability documented as “not for surgery”.

^c Restricted to those who had a completed surgical resection ($n=585$).

Table 2
Compliance with diagnosis and staging quality indicators, overall and according to completion of surgery and margin status.

Diagnosis and Staging Quality Indicator (<i>D</i> = number of patients undergoing surgery)	Number eligible ^a (n)	Overall Compliance <i>N</i> / <i>D</i> , (% CI)	Completed Resection <i>N</i> / <i>D</i> , (% CI)	Abandoned Resection <i>N</i> / <i>D</i> , (% CI)	Clear Margin ^b Status (<i>R0</i>) <i>N</i> / <i>D</i> , (% CI)	Positive Margin Status ^b (<i>R1</i> / <i>R2</i>) <i>N</i> / <i>D</i> , (% CI)	Missing <i>N</i> / <i>D</i> , (% CI)
Time from GP/IED referral to primary treatment within 60-526 days (<i>N</i> = number of patients with time from referral to neo-adjuvant therapy or surgery within 60 days)	526	446/526 (85, 81–88)	376/433 (87, 83–90)	70/93 (75, 65–84)	199/228 (87, 82–91)	152/174 (87, 81–92)	25/31 (81, 65–93)
Documented pancreatic protocol CT scan for diagnosis and/or staging (<i>N</i> = number of patients with a documented PPCT scan)	577	315/577 (55, 50–59)	251/474 (53, 48–58)	64/103 (62, 52–72)	118/238 (50, 43–56)	105/185 (57, 49–64)	28/51 (55, 40–69)
Documented baseline CA19-9 before treatment (<i>N</i> = number of patients with a documented CA19-9 before surgery)	644	584/644 (91, 88–93)	482/534 (90, 87–93)	102/110 (93, 86–97)	229/259 (88, 84–92)	200/216 (93, 88–96)	53/59 (90, 79–96)
Documented ECOG at presentation and/or ASA at a diagnostic procedure/diagnosis (<i>N</i> = number of patients with a documented ECOG and/or ASA)	689	442/689 (64, 60–68)	369/570 (65, 61–69)	73/119 (61, 52–70)	204/276 (74, 68–79)	118/229 (52, 45–58)	47/65 (72, 60–83)
Disease management discussed at an MDT meeting (<i>N</i> = number of patients discussed at an MDT meeting)	566	401/566 (71, 66–74)	332/466 (71, 67–75)	69/100 (69, 59–78)	174/231 (75, 69–81)	114/182 (63, 55–70)	44/53 (83, 70–92)
Disease management for all patients discussed at an MDT meeting prior to surgery (<i>N</i> = number of patients discussed at an MDT prior to surgery)	386	349/386 (90, 87–93)	288/317 (91, 87–94)	62/69 (90, 80–96)	154/171 (90, 85–94)	103/110 (94, 87–97)	31/36 (86, 71–95)

N = numerator; *D* = denominator.

^a Number eligible is determined on available variables data for QI calculation, i.e. excludes patients missing associated variables data from the denominator for QI calculation; e.g. missing GP/IED referral date.

^b Margin status restricted to those who had a completed surgical resection (*n* = 585).

^c Margin status not documented (*n* = 6), or missing – awaiting access to pathology results from participating hospital.

the group of patients who underwent resection with a positive margin (*n* = 118/229, 52 %) compared to overall.

3.3. The association between patient characteristics, compliance with quality indicators, and abandoned resections or positive margins

Tables 3–6 summarise the univariable and multivariable associations between abandoned surgery or positive margins, patient characteristics and compliance with QIs.

When assessing the relationship between patient characteristics and abandoned surgery or positive margins, there was a 61 % lower odds of a completed resection in those classified as having borderline resectable disease (*OR*=0.39, 95 % *CI*, 0.22 - 0.71), and 82 % lower odds in those with locally advanced disease (*OR*=0.18, 95 % *CI*, 0.08-0.39) compared to those classified as having resectable disease at diagnosis. Further, there was 40 % lower odds of a complete resection if imaging was undertaken more than 30 days prior to surgery compared to imaging within 30 days of surgery. However, both the univariable and adjusted models were not statistically significant overall. The only patient characteristic significantly associated with a positive surgical margin as a prognostic factor in a multivariable analysis was ECOG performance status. However, our data showed that approximately 80 % of patients did not have ECOG clearly documented. This category showed reduced odds of a R0 resection (*OR*=0.45, 95 % *CI*, 0.25-0.82). In comparison, the QI that tested the association of documentation of ECOG and/or ASA at presentation, had 90 % increased odds of a R0 margin resection. Patients who underwent primary treatment within 60 days of referral had over two times increased odds of a complete resection and this was statistically significant. In comparison, there was a statistically non-significant result showing less odds of an R0 resection when surgery and/or neo-adjuvant therapy occurred earlier.

3.4. Reasons for surgery abandoned intraoperatively and length of stay

An additional medical record audit was undertaken for fifty patients (50/119, 42 %) for whom surgery was abandoned intraoperatively to understand the reasons for incomplete surgery. Fifty-six percent (*n*=28/50) were abandoned due to a finding of locally advanced pancreatic cancer, and of these, most (89 %, *n*=25/28) had vascular adherence or tumour invasion of the superior mesenteric vessels, portal vein and/or hepatic artery. Of these 25 patients, only 13 patients (52 %) had previously been staged with a PPCT. Further, 20 (40 %) surgeries were abandoned due to a finding of unexpected metastatic disease, mainly liver lesions (65 %, *n*=13/20) followed by other metastatic lesions involving the peritoneum, small bowel, and colon not identified on prior imaging. Of the 20 patients with metastases, 70 % (*n*=14/20) had a PPCT scan. One patient was taken to surgery for an exploratory laparotomy secondary to gastric outlet obstruction and another had surgery abandoned due to undiagnosed severe liver disease. The median length of stay (LOS) for patients who had their surgery abandoned was 9 days (range 2–71 days).

4. Discussion

We evaluated a large cohort of patients with PC who underwent an attempted resection. Previous studies have mainly assessed associations between surgical factors such as institutional volume, patient selection, treatment algorithms with outcomes such as morbidity (perioperative complications), mortality and overall survival [11,17]. However, to our knowledge, this is the

Table 3
Association between patient and tumour characteristics and having a completed resection.

Characteristics	Univariable analysis			Multivariable analysis		
	OR	95 % CI	P value	OR	95 % CI	P value
Age Group^a						
<55	Reference					
55–64	0.93	0.46–1.86	0.691	0.89	0.44–1.78	0.371
65–74	0.95	0.50–1.81		0.92	0.48–1.74	
>75	0.79	0.40–1.56		0.77	0.39–1.52	
Sex^a						
Female	Reference					
Male	0.70	0.47–1.05	0.081	0.70	0.46–1.04	0.371
ECOG Performance Status^a						
0 - fully active	Reference					
1	0.49	0.21–1.14	0.076	0.47	0.20–1.11	0.130
>2	0.58	0.16–2.09		0.52	0.14–1.92	
Not clearly documented	1.00	0.53–1.89		1.01	0.53–1.92	
Resectability at Diagnosis^b						
Resectable	Reference					
Borderline Resectable	0.46	0.27–0.79	0.001	0.39	0.22–0.71	0.005
Locally advanced	0.22	0.11–0.46		0.18	0.08–0.39	
Not clearly documented	0.79	0.45–1.36		0.68	0.38–1.21	
Site of Tumor^a						
Head	Reference					
Neck	0.73	0.28–1.85	0.354	0.71	0.28–1.82	0.416
Body	1.44	0.71–2.92		1.40	0.69–2.84	
Tail	0.89	0.43–1.84		0.89	0.43–1.86	
Uncinate process	0.49	0.23–1.02		0.48	0.23–1.01	
Pancreas (not otherwise specified)	0.83	0.30–2.27		0.78	0.28–2.18	
Imaging at diagnosis or following neoadjuvant therapy (days prior to surgery)^b						
≤30 days	Reference					
>30 days	0.60	0.38–0.94	0.024	0.58	0.37–0.92	0.020

^a Adjusted for age, sex; age and sex mutually adjusted.

^b Adjusted for age, sex, ECOG, annual hospital surgical volume.

Table 4
Association between patient characteristics and odds of an R0 margin resection.

Characteristics	Univariable analysis			Multivariable analysis		
	OR	95 % CI	P value	OR	95 % CI	P value
Age Group						
<55	Reference					
55–64	1.24	0.73–2.12	0.826	1.28	0.74–2.18	0.642
65–74	1.27	0.78–2.07		1.30	0.80–2.13	
>75	1.29	0.76–2.19		1.31	0.77–2.23	
Sex						
Female	Reference					
Male	1.23	0.90–1.69	0.190	1.25	0.91–1.71	0.642
ECOG Performance Status^b						
0 - fully active	Reference					
1	1.05	0.44–2.53	0.013	0.88	0.35–2.19	<0.001
>2	0.81	0.23–2.83		0.66	0.18–2.46	
Not clearly documented	0.47	0.27–0.83		0.45	0.25–0.82	
Resectability at Diagnosis^a						
Resectable	Reference					
Borderline Resectable	1.20	0.77–1.86	0.185	1.30	0.83–2.06	0.330
Locally advanced	1.89	0.86–4.13		1.98	0.90–4.37	
Not clearly documented	0.90	0.61–1.35		0.93	0.62–1.39	
Site of Tumor^a						
Head	Reference					
Neck	1.09	0.48–2.47	0.609	1.09	0.48–2.47	0.722
Body	0.79	0.49–1.27		0.78	0.48–1.27	
Tail	1.38	0.74–2.58		1.40	0.75–2.62	
Uncinate process	1.67	0.77–3.61		1.68	0.77–3.64	
Pancreas (not otherwise specified)	1.17	0.50–2.74		1.11	0.47–2.65	
Imaging at Diagnosis or following neoadjuvant therapy (days prior to surgery)^a						
≤30 days	Reference					
>30 days	1.21	0.86–1.71	0.279	1.22	0.86–1.73	0.259

^a Adjusted for age, sex; age and sex mutually adjusted.

^b Adjusted for age, sex, resectability, annual hospital surgical volume.

Table 5
QIs and odds of a completed resection.

Quality indicator	Univariable analysis			Multivariable analysis		
	OR	95 % CI	P value	OR	95 % CI	P value
Time from GP/ED referral to primary treatment within 60 days ^b	2.17	1.25–3.75	0.013	2.12	1.19–3.76	0.010
Documented pancreatic protocol CT scan for diagnosis and/or staging ^a	0.69	0.44–1.06	0.079	0.71	0.46–1.10	0.221
Documented baseline CA19-9 before treatment ^a	0.73	0.34–1.58	0.648	0.82	0.37–1.80	0.614
Documented ECOG at presentation and/or ASA at a diagnostic procedure ^a	1.16	0.77–1.74	0.485	1.27	0.84–1.93	0.251
Disease management discussed at an MDT meeting ^a	1.11	0.70–1.78	0.484	1.24	0.77–2.02	0.378
Disease management for all patients discussed at an MDT meeting prior to surgery ^a	1.08	0.45–2.57	0.738	1.23	0.51–2.97	0.646

^a Adjusted for age, sex, neoadjuvant treatment.^b Adjusted for age, sex, ECOG, resectability, neoadjuvant treatment, annual hospital surgical volume.**Table 6**
QIs and odds of an R0 margin resection.

Quality indicator	Univariable analysis			Multivariable analysis		
	OR	95 % CI	P value	OR	95 % CI	P value
Time from GP/ED referral to primary treatment within 60 days ^a	0.73	0.43–1.24	0.251	0.72	0.42–1.24	0.238
Documented pancreatic protocol CT scan for diagnosis and/or staging ^a	0.87	0.62–1.25	0.227	0.89	0.62–1.27	0.427
Documented baseline CA19-9 before treatment ^a	0.70	0.38–1.27	0.463	0.65	0.35–1.18	0.157
Documented ECOG at presentation and/or ASA at a diagnostic procedure ^b	2.24	1.62–3.11	< 0.001	1.90	1.32–2.73	< 0.001
Disease management discussed at an MDT meeting ^c	1.76	1.21–2.58	0.003	1.20	0.77–1.87	0.413
Disease management for all patients discussed at an MDT meeting prior to surgery ^a	0.56	0.24–1.31	0.180	0.50	0.21–1.19	0.121

^a Adjusted for age, sex, neoadjuvant treatment.^b Adjusted for age, sex, resectability, neoadjuvant treatment, annual hospital surgical volume.^c Adjusted for age, sex, ECOG, resectability, neoadjuvant treatment, annual hospital surgical volume.

first study evaluating six QIs that represent measures of best practice to determine the association between compliance with these measures and positive surgical margin or abandoned surgery. In the endeavour to improve the quality of care related to completed and margin resections, outcomes such as survival and quality of life may also be positively impacted [18].

In 17 % of patients with an attempted resection, surgery was abandoned due to locally advanced or metastatic disease. This is lower than a previous Australian study conducted in Queensland and NSW in 2009–2011, which found an incomplete resection rate of 24 % [19]. Just over half of the patients who had a completed resection and a known margin status (54 %) had a complete tumour excision (R0 resection). This is somewhat lower than in an earlier study in Australia conducted over a decade ago in which a 64 % clear margin status was reported [20]. However, the definition for clear margin status (stratified by increments of 0.5 mm) in that study differs to our definition of ≥ 1 mm margin clearance which may explain the observed difference. In comparison, an international study reported a R0 margin resection of 20 % following the evaluation of the revised definitions for circumferential R0 compared to R1 margin status and the introduction of standardised protocols for rigorous margin assessment in Europe [21].

Patients in whom surgery was abandoned intraoperatively had a median LOS of approximately 10 days. This is similar to a median LOS of 12 days reported in other studies for pancreatic surgery, which may indicate that recovery times are prolonged and post-operative morbidity increased in patients with abandoned surgery given that there was no resection actually performed [22]. Abandoned surgery may be the result of inadequate or insensitive diagnostic and staging techniques or that surgeons are willing to attempt more aggressive resections on tumours with borderline disease or after neoadjuvant treatment based on improvements in surgical techniques [19].

These results indicate the need to optimise surgical decision-making. Despite improvements in diagnostic techniques, a subset of patients may undergo laparotomy for a clear determination

of resectability [23]. An alternative reason for an attempted resection in patients with borderline or locally advanced disease may be the use of conversion surgery following neoadjuvant or induction therapy [24,25]. However, the use of conventional CT imaging following neoadjuvant therapy does not always distinguish between residual tumour and scarring from tumour regression due to the fibrotic and infiltrative nature of PC. As a result, it can be difficult to distinguish between residual tumour and scarring from tumour regression. A response may be presumed if the tumour appears stable or has reduced in size, and tumour markers have not increased [26,27]. Further, although upfront surgical resection remains the current evidence-based standard of care in clearly resectable disease, future directions require an understanding of the biological responses to neoadjuvant therapy as a recently adopted standard in borderline disease [25].

A PPCT continues to be the optimal modality for diagnosis and is highly predictive of the extent of locoregional extension and vascular involvement. Whereas magnetic resonance imaging (MRI) has some advantages in detecting small tumours, or distant metastases, it is often reserved for the diagnosis rather than the staging of PC, is associated with higher costs and lower availability [27–30]. Our study shows low overall compliance (55 %) with a documented PPCT for diagnosis and/or staging, although there were no statistically significant association with adverse surgical margin or abandoned surgery. Half of the patients who had vascular involvement as cause of aborted surgery had a PPCT scan, and 70 % identified with metastatic lesions had a PPCT. The lack of association between the use of PPCT and abandoned surgery or positive surgical margins due to undiagnosed metastatic disease suggests that the current staging technology is inadequate and that other more sensitive, pancreatic imaging approaches are needed; these may include functional imaging such as perfusion CT, dynamic contrast-enhanced MRI, diffusion weighted imaging and radiomics approaches. Such approaches may improve the staging of pancreatic cancer, potentially reducing the risk of having to abandon surgery [28]. Further, the time interval between

imaging and surgery may play an important role in the detection of metastatic disease with one study recommending that patients should be imaged within 25 days prior to surgery [31]. Our study showed a 40 % reduction in the odds of a completed resection if imaging was undertaken beyond 30 days prior to surgery. This highlights the need to ensure that imaging is undertaken close to surgery to maximise the likelihood of a complete resection being performed.

We found that resectability at diagnosis was not clearly documented for 30 % of patients following perusal of the medical records by trained data collectors. Proper documentation of resectability is recommended to formulate a clear treatment pathway within a multidisciplinary setting. Further qualitative research may provide further insights into the reasons for this variation.

Two QIs were associated with lower odds of an adverse surgical outcome following adjustment for patient characteristics and surgical volume. *Time from referral to surgery or first neoadjuvant therapy within 60-days* was associated with improved odds of a completed resection. This finding validates the clinical advantage of reducing delays to treatment in potentially resectable PC [32]. A general practice setting is often the first point of contact for patients with symptoms suspicious of PC and hence these clinicians play a crucial role in the timely referral of patients to specialist services for diagnosis [33]. Patients may also be diagnosed in a hospital setting following symptomatic presentation to the hospital emergency department [34]. In addition, factors associated with delays from diagnosis to treatment may include surgical wait times potentially compounded by centralisation of care, older age, comorbidities that may require a more extensive workup, and lower socioeconomic status [34–36]. Finally, it's likely that a shorter time to surgery reflects a smaller tumour burden and that patients with larger resectable or borderline resectable tumours that receive neoadjuvant chemotherapy have worse outcomes because of worse biology and/or later presentation.

Given that approximately 80 % of patients did not have ECOG clearly documented at diagnosis, ASA at presentation was used as a proxy measure for performance status with both deemed as a surrogate measure for capturing comorbidity profile [37]. The association between the *documentation of ECOG status and/or ASA at presentation* and improved R0 resection margins is not immediately obvious but likely reflects greater skills within the surgical community familiar with oncologic principles as well as surgery undertaken at larger volume centres with better documentation processes or it may reflect selective documentation. It is possible that ECOG and/or ASA is more often recorded when a patient is clearly fit for surgery or, conversely, when poor health needs to be documented as a reason to avoid surgery. In cases where fitness is less certain, documentation may be less consistent, which could contribute to this association.

This study provides new knowledge on timely treatment from referral and its impact on abandoned surgery. However, we did not investigate whether imaging was done for symptoms or incidental findings, nor the duration of symptoms prior to diagnosis. In addition, performance status documented at presentation and/or at a diagnostic procedure likely serves as a surrogate measure for quality of care including the role of MDT discussions and its association with a lower likelihood of adverse surgical outcomes. Discussions within an MDT setting that include a range health care professionals who manage PC are recommended by numerous clinical guidelines to support comprehensive decision-making across all disease stages. For the provision of high-quality care, our study focused on the process of whether patients were discussed at an MDT, and if this discussion took place prior to surgery. Although not statistically significant for adverse outcomes in the

multivariable analysis, we have previously reported on the significance of MDT meetings on survival in patients with advanced disease [16].

We have comprehensively discussed the limitations for prospectively collected observational data elsewhere [15,16]. These include important patient characteristics that were not routinely captured by the registry, such as race and ethnicity as well as comorbidities. This may have allowed more comprehensive adjustment of the QIs, notwithstanding that all patients evaluated in this study underwent some form of pancreatic resection. Further, at the point of data analysis, margin status for 72 patients were not available. Although, compliance with QIs for this group of patients was evaluated, association with margin status could not be conducted. Finally, in this study, we did not assess the impact of compliance with QIs on survival. In addition, we have previously reported our results highlighting the association between 22 evidence-based QIs and survival [16]. Referral to any treatment within 60 days was not associated with improved survival outcomes for the potentially resectable group.

5. Conclusion and future considerations

This study highlights the need for improving clinical pathways for early detection and treatment to improve the effectiveness of quality care for patients with potentially resectable PC. Further research with a focus on improving clinical pathways for early detection and treatment for effective quality of care are urgently required [38]. To provide greater clinical insight, future research focusing on a more granular analysis examining whether outcomes vary by timing of intervention may identify potential inflection points for optimal care. Further, improved methods for assessment of resectability at diagnosis are essential to optimise surgical decision-making and reduce the risk of positive margins, or surgery being abandoned intraoperatively. Timely progression to primary treatment had the most significant association with having a complete resection and whilst a larger tumour burden likely reflects underlying biology, it is feasible that an earlier diagnosis may increase the proportion of optimally resected patients and lead to improvements in patient outcomes. Finally, quality of care can differ substantially across different healthcare delivery systems and regions both within a high income or resource-limited setting. For system level improvements in quality, it is critical at the very least, to monitor quality of care within regions and implement contextualised improvements.

Author contributions

JRZ, AM, AE, SME, and REN were involved in the design of this study. BB and HE undertook the audit and data quality checks. AM analysed the data and prepared the manuscript. DC and CHCP provided surgical oversight for analysis. KH and JS provided surgical expertise and the data for New South Wales. EG, LJI, and BB provided data oversight and BB contributed to data collection. REN, DG, JGK, NDM, KW are investigators on this study. All authors interpreted the results, edited and reviewed the different versions of the manuscript and gave approval for submission of the final manuscript.

Data transparency statement

The data that support the findings of this study are available on request from the Upper Gastrointestinal Cancer Registry (<https://uigcr.org.au/>). The data are not publicly available due to the privacy of patient information.

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Declaration of competing interest

The authors have no conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pan.2025.09.029>.

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