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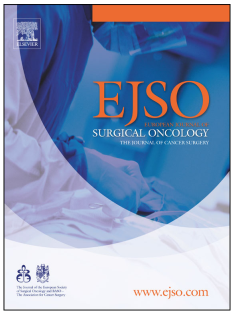

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The relationship between hospital volume and post-operative mortality rates for upper gastrointestinal cancer resections: Scotland 1982-2003

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Abstract

Background: Centralisation of surgical treatment of cancer has resulted in improved outcomes. We aimed to determine evidence of benefit for specialised management of upper gastrointestinal cancer in high-volume centres in Scotland.

Methods: Discharge records of patients undergoing oesophagectomy, gastrectomy, hepatectomy or pancreatectomy between 1982 and 2003 were identified. Hospital data were analysed on a year-by-year basis to derive ‘hospital-years’. Hospital-years were divided into quartiles by volume, and were analysed with regard to in-hospital mortality during the operative admission [Chi-square test (χ^2) and Chi-square test for trend (χ^2_{trend})].

Results: 10,625 patients and 982 in-hospital deaths were included. In-hospital mortality rates declined during the study period: oesophagectomy 11·7% to 7·9%; gastrectomy 11·2% to 7·2%; hepatectomy 11·1% to 3·0%; and pancreatectomy 8·3% to 4·9%. For all resections except gastrectomy, mortality decreased as quartile of hospital-year volume increased (oesophagectomy: χ^2p = 0·006, χ^2_{trend}p = 0·001; hepatectomy: χ^2p = 0·004, χ^2_{trend}p = 0·003; pancreatectomy: χ^2p = 0·002, χ^2_{trend}p = 0·001). ORs of death were lower for oesophagectomy (OR = 0·58; 95%CI = 0·39, 0·88; p = 0·009) and pancreatectomy (OR = 0·35; 95%CI = 0·19, 0·64; p<0·001) in hospital-years within highest-volume quartiles compared with lowest. Scattergraphs of all resection types demonstrated inverse power relationships between number of resections per hospital-year and mortality.

Conclusion: Concentration of cancer care has had major effects on health service delivery in Scotland. Centralisation should be supported in surgical management of upper gastrointestinal cancer.

Keywords: Surgery; oesophageal cancer; gastric cancer; pancreatic cancer; hepatocellular cancer; mortality

Introduction

Studies have demonstrated improved survival of patients with different types of upper gastrointestinal (GI) cancer, including oesophageal, gastric, pancreatic and hepatocellular cancer, undergoing surgical resection in high-volume, specialist centres[1-3]. For this reason, the United Kingdom Department of Health Clinical Outcomes Group has recommended that patients with oesophageal and gastric cancer should be referred to specialist units serving a population of 1-2 million[4]. Such units should each expect to manage at least 100 patients with oesophageal cancer and 150 patients with gastric cancer annually, with approximately 100 patients having resections. Similarly, patients with pancreatic cancer should be referred to specialist units serving a population of 2-4 million[4]. Such units should expect to discuss approximately 200 new patients annually.

In Scotland, the extent of centralisation and sub-specialisation of surgical practice, with subsequent effects on service provision and patient care, are largely unknown. However, we hypothesised that such forces may have resulted in a drive towards the development of high volume centres. In order to investigate changes in service demand and the effect of centralisation, we aimed to examine the use and outcome of elective upper GI cancer resection in Scotland between 1982 and 2003. In particular, we aimed to analyse post-operative in-hospital mortality rates for oesophagectomy, gastrectomy, hepatectomy and pancreatectomy performed electively for cancer, and examine the influence of hospital volume.

Methods

Data Source: Post-operative in-hospital records and mortality data for all elective oesophageal, gastric, hepatic and pancreatic cancer resections performed in Scotland between 1982 and 2003 were obtained from Information Services Division (ISD) Scotland, a support service of NHS Scotland. The database used was SMR1/01, an episode-based record relating to all inpatients and day cases discharged from non-obstetric and non-psychiatric specialties. Admissions during which an inpatient underwent elective surgical resection and also died were identified. Operation codes used to identify patients were those of the Office of Population Censuses and Surveys (OPCS) Classification of Surgical Operations (3rd Revision) for patients treated before January 1989, and OPCS Classification of Surgical Operations and Procedures (4th Revision) for later patients: oesophagectomy OPCS3 291.2 and OPCS4 G01/G02/G03; gastrectomy OPCS3 422/423 and OPCS4 G27/G28; hepatectomy OPCS3 500·1/500·3/509·4 and OPCS4 J02/J03; and pancreatectomy OPCS3 531/532 and OPCS4 J55/J56/J576/J58. Cancer diagnosis codes used to identify patients were those of the World Health Organization (WHO) International Classification of Diseases (ICD): Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death, 9th Revision for patients treated before April 1996, and WHO International Classification of Diseases and Related Health Problems, 10th Revision for later patients: oesophageal cancer ICD9 150 and ICD10 C15; gastric cancer ICD9 151 and ICD10 C16; cancer of liver and intra-hepatic bile ducts ICD9 155 and ICD10 C22; and pancreatic cancer ICD9 157 and ICD10

C25. In-hospital mortality was defined as death during the admission for which the patient underwent surgery, and was not risk-adjusted.

Statistical Analysis: Crude population-based rates (PBR) of cancer resection utilisation were calculated using revised mid-year population estimates from the General Register Office for Scotland[5]. Comparison between groups was performed using Pearson's Chi-square test ('χ^2p') and linear-by-linear association ('χ^2_{trend}p'). Change in average annual hospital volume per year was assessed using Pearson's correlation coefficient. Within Scotland, few hospitals are likely to reach criteria for high volume according to international standards, but for analysis purposes, data from all hospitals for all 22 years of collection were analysed independently to derive 'hospital-years' i.e. one hospital would have 22 associated "hospital-year" mortality rates if it performed a resection every year for the entire study period. Thus, any individual hospital might be identified as a high-volume centre one year but a low-volume centre the next, or vice-versa. Odds ratios (OR) of in-hospital death (with 95% confidence intervals) were calculated. Curve-fitting and non-linear regression of scattergraphs was performed following exclusion of those hospital-years with a mortality rate of zero. Curve equations were solved for y values of published recommended mortality rates. The Association of Upper Gastrointestinal Surgeons of Great Britain and Ireland (AUGIS), the British Society of Gastroenterology (BSG), and the British Association of Surgical Oncology recommend a post-resectional in-hospital mortality rate of ≤10% for oesophagectomy, ≤10% for total gastrectomy and ≤5%

for subtotal gastrectomy[6]. However, the AUGIS Database Report 2004 demonstrated that average post-resectional in-hospital mortality rates for cancers of the oesophagus, stomach and oesophago-gastric junction treated in England and Wales were approximately 5%[7]. Therefore, curve equations were solved for oesophagectomy and gastrectomy using mortality rates of both ≤10% and ≤5%. The Pancreatic Section of the BSG, the Pancreatic Society of Great Britain and Ireland, AUGIS, the Royal College of Pathologists, and the Special Interest Group for Gastro-Intestinal Radiology recommend in-hospital mortality rates of ≤5% for pancreatectomy[8]. We have concluded that an in-hospital mortality rate of ≤5% is suitable for hepatectomy[9]. All analyses were performed using SPSS 13·0 (Chicago, IL, USA). Statistical significance was set at $p<0{\cdot}05$ level.

Results

Utilisation Rates: Sixty-one Scottish hospitals performed one or more elective upper GI cancer resection between 1982 and 2003. The total numbers of resections and post-operative in-hospital deaths, and the average in-hospital mortality rates over the 22-year study period are shown in Table 1.

The annual number of oesophagectomies rose from 82 in 1982 to a peak of 296 in 1995, but then declined steadily to 164 in 2003. Annual hepatectomies increased from 1 in 1982 to 79 in 2003, whereas annual pancreatectomies increased from 16 to 81. In contrast, the annual number of gastrectomies demonstrated a greater than 50% reduction from 232 in 1982 to 112 in 2003. As the population of Scotland remained relatively static throughout the whole study period (1982: 5·17 million; 2003: 5·06 million), the patterns of annual population-based utilisation were similar to the patterns of annual resection number. The PBR of oesophagectomies rose from 1·59 per 100 000 head of population in 1982 to a peak of 4·84 in 1995, but then declined steadily to 3·24 in 2003 (χ^2 $p<0{\cdot}001$; χ^2_{trend} $p<0{\cdot}001$). Annual hepatectomies increased from 0·02 per 100 000 in 1982 to 1·56 in 2003 (χ^2 $p<0{\cdot}001$; χ^2_{trend} $p<0{\cdot}001$), whereas annual pancreatectomies increased from 0·31 per 100 000 to 1·60 (χ^2 $p<0{\cdot}001$; χ^2_{trend} $p<0{\cdot}001$). However, the annual number of gastrectomies demonstrated a greater than 50% reduction from 4·49 per 100 000 in 1982 to 2·21 in 2003 (χ^2 $p<0{\cdot}001$; χ^2_{trend} $p<0{\cdot}001$).

Hospital Volume: Between 1982 and 2003, the number of hospitals performing gastric resections decreased by 45% from 42 to 23. Between 1995 and 2003, the number of hospitals performing oesophagectomies also declined by 46% from 28 to 15. However, the numbers of centres performing hepatic and pancreatic resections remained relatively static over the entire 22-year study period (hepatectomy – approx 6 hospitals per year; pancreatectomy – approx 11 hospitals per year). These observations translated into considerable yearly increases in the average annual resection volume of hospitals performing oesophagectomies (r^2=0·911; p<0·001), hepatectomies (r^2=0·925; p<0·001) and pancreatectomies (r^2=0·899; p<0·001) across the whole study period, but little change in the average volume of centres offering gastrectomy (n.s.) (Figure 1a). Across the study period, the percentage of oesophagectomies (1982 – 28·0%, 2003 – 59·1%), hepatectomies (1982 – 0·0%, 2003 – 98·7%) and pancreatectomies (1982 - 0·0%, 2003 – 88·9%) performed in the highest-volume centres increased significantly (χ^2 p<0·001; χ^2_{trend} p<0·001) (Figure 1b). Gastrectomy also demonstrated a significant change in the percentage of resections performed in the highest-volume centres, although there was no evidence of a linear trend (1982 - 37·1%, 2003 - 36·6%; χ^2 p<0·001; χ^2_{trend} n.s.).

Post-Operative In-Hospital Mortality: Annual mortality rates fluctuated considerably from year to year. However, when the 22-year mortality data were analysed using averages over several years (5-year averages plus the average of the last 2 years of the study), it was observed that the mortality rates of all types of resection appear to have declined steadily, although these reductions did not reach statistical significance in all cases: oesophagectomy - 11·7% to 7·9% (n.s.); gastrectomy – 11·2% to 7·2% (χ^2 p=0·032; χ^2_{trend} n.s.); hepatectomy - 11·1% to 3·0% (χ^2 p=0·049; χ^2_{trend} p=0·023); and pancreatectomy - 8·3% to 4·9% (n.s.) (Figure 2).

For all resections except gastrectomy, post-operative in-hospital mortality rates decreased as quartile of hospital-year volume increased (oesophagectomy - χ^2 p=0·006, χ^2_{trend} p=0·001; hepatectomy - χ^2 p=0·004, χ^2_{trend} p=0·003; pancreatectomy - χ^2 p=0·002, χ^2_{trend} p=0·001), although the relationship was not straightforward in all cases (see Discussion) (Table 2). Furthermore, the odds ratio of in-hospital death was significantly reduced for oesophagectomy (OR=0·58; 95%CI 0·39, 0·88; p=0·0089) and pancreatectomy (OR=0·35; 95%CI 0·19, 0·64; p<0·001) in those hospital-years with the highest volumes compared with the lowest. Whilst the odds ratio for hepatectomy was also reduced (OR=0·33; 95%CI 0·10, 1·05; n.s.) in highest-volume hospital-years, this decrease did not reach statistical significance.

For each type of resection, the relationship between the number of resections performed in each hospital-year and post-operative in-hospital mortality rate was best defined by equations involving an inverse power function (Figure 3a-d). Solving these equations for y values of published recommended mortality rates[2-6] indicated that surgical units must perform at least 19 oesophagectomies or 16 gastrectomies per year to ensure <u>average</u> mortality rates of less than 10%, or at least 51 oesophagectomies or 41 gastrectomies per year to ensure average mortality rates of less than 5%. Furthermore, a unit must perform at least 24 hepatectomies or 33 pancreatectomies per year to ensure average mortality rates of less than 5%. During the last five years of the study (1999-2003), only 4 of the 22 hospitals offering oesophagectomy performed more than 19 oesophageal resections in a year, and only 2 hospitals achieved this statistic in all 5 years. Furthermore, only 2 of the 28 hospitals offering gastrectomy performed more than 16 gastric resections in a single year, and no hospitals achieved this number in all 5 years. No hospitals performed either 51 oesophagectomies or 41 gastrectomies in a year, or achieved the COG recommendation of 100 annual oesophagogastric resections. Only 1 of the 8 hospitals offering hepatectomy between 1999 and 2003 performed more than 24 resections annually, but it achieved this in all 5 years. The same centre was only 1 of 11 hospitals offering pancreatectomy that ever performed more than 33 resections in a year (in 2001). Between 1999 and 2003, the average in-hospital mortality rates in this centre were 1.5% for hepatectomies and 5.1% for pancreatectomies.

Discussion

Volume-Outcome Relationship in Non-Upper GI Surgery: Increased hospital volume has been shown to be associated with reduced post-operative mortality in oesophagectomy[1;10-12], gastrectomy[2], hepatectomy[3;13;14], pancreatectomy[3;14-16], colectomy[2], pelvic exenteration[3], pneumonectomy[3], paediatric cardiac surgery[17], carotid endarterectomy[18] and abdominal aortic aneurysm (AAA) repair[19]. Cancer patients treated in high-volume hospitals have been shown to experience reduced rates of post-operative complications and improved 5-year survival[20;21]. In North America, selective hospital referral strategies based on minimum volume standards, processes of care and direct outcome measurement have been proposed as methods of reducing mortality following oesophagectomy, pancreatectomy, AAA repair, coronary artery bypass grafting and percutaneous coronary interventions[22]. However, the potential association between increased hospital volume and improved surgical outcomes remains a controversial issue in which a number of negative studies have also been published[23;24].

Volume-Outcome Relationship in Upper GI Surgery in Scotland: The results of the present study support the concept that post-operative in-hospital upper GI cancer patient mortality is decreased in Scotland when resection is performed in high-volume centres, particularly in patients with oesophageal, hepatic and pancreatic cancer. In closer detail, our results show that between 1982 and 2003, the post-operative in-hospital mortality rates of oesophagectomy, hepatectomy and pancreatectomy decreased in the face of dramatically increased population-based rates of resection. Over the same time period, the percentage of resections being performed in high volume centres also increased significantly. Factors that may have contributed to the decline in mortality in high volume centres would have included the development of specialist multidisciplinary teams with improved patient selection[25], and advances in surgical, anaesthetic and post-operative care[26]. However, some of these changes will have also taken place in low volume centres, and thus some temporal improvement in mortality rates may have occurred inevitably outwith the influence of hospital volume.

Analysis of data by quartile of hospital-year volume demonstrated that operations performed during highest-volume hospital-years were significantly associated with reduced post-operative mortality for oesophagectomy, hepatectomy and pancreatectomy, compared with the lowest volume hospital-years. However, the relationship between volume and outcome was not straightforward. The “unusually” high mortality rate observed within hospital-years performing 2 hepatectomies (i.e. second volume quartile - see Table 2) might be explained by an artefactually low mortality rate within the lowest volume quartile (only 1 resection annually) or by the relatively small number of operations performed within any of the 3 lowest quartiles. However, it is interesting to note that, compared with hospital-years performing 2 hepatectomies, the OR of post-operative in-hospital death was significantly lower in the highest volume quartile (performing 7 or more hepatectomies annually) (OR=0·16; 95%CI 0·05, 0·52; p<0·001). Furthermore, if mortality data from the 3 lowest volume quartiles for hepatectomy are combined and compared with the highest volume quartile, a significant difference in mortality is observed (6.7% versus 2.1%; p=0.0019). However, the increase from 5·3% to 6·9% in the mortality rate of pancreatic cancer patients treated in hospital-years performing 6 or more pancreatectomies (i.e. the highest volume quartile – see Table 2) compared with hospital years performing 3 to 5 pancreatectomies (the third quartile) is more difficult to explain. Possible explanations include variation in patient fitness; poor patient selection; differences in surgical technique; differing thresholds for operating on patients with disease which is at the limit of resectability; and radicality of the surgery (i.e. lymphadenectomy and multivisceral resection) which expose patients to higher risks of post-operative morbidity and mortality. These factors have not been analysed in the present study.

Gastrectomy data do not appear to demonstrate a significant effect of hospital volume on mortality. However, other reasons may also have contributed to the lack of a positive volume-outcome relationship. Firstly, the number of gastric resections declined by approximately 50% over the study period, presumably secondary to the decreasing incidence of gastric cancer in Western Europe. Secondly, the majority of hospitals performing gastrectomy in Scotland are still of relatively low volume. This finding would be consistent with arguments proposed by other authors that cancer centres in Scotland are not yet of sufficient critical mass[27]. It could also be argued that the reduction in gastric resection for benign disease over the study period has impacted on training, thus reducing any potential volume-outcome relationship still further.

Perhaps the strongest evidence for a significant effect of hospital volume on patient outcome was the inverse power relationship observed between hospital-year volume and in-hospital mortality rate for all types of resection. Solving the curve equations for recommended mortality rates provided ‘ideal volume parameters’ for centres offering different types of upper GI cancer resection. It could be argued that these ‘ideal volume parameters’ are likely to be an over-estimate as all hospital-years with a mortality rate of zero must be excluded to generate the curve equations. However, although zero post-operative deaths should represent our ultimate goal, it must also be appreciated that the concept of a hospital offering long-term surgical treatment of upper GI cancer with zero mortality remains a theoretical one that lies outwith the bounds of current medical practice. Therefore, the observed inverse curves are unlikely to ever touch the X-axis. In any case, these curves imply that centralisation and specialisation improve patient outcome, but that a sufficient number of high-volume centres have not yet been established to treat satisfactorily upper GI cancer in Scotland. Another important point raised by scattergraph analysis is that the chosen method of statistical interrogation may affect the overall conclusions of a volume-outcome study. Although analysis of mortality data by quartile of hospital-year volume could demonstrate no significant results for gastrectomy, scattergraph analysis appeared to demonstrate an inverse relationship between in-hospital mortality rate and the number of gastric resections performed per hospital-year.

Comparisons With Other Studies: The findings of the present study would appear to contradict those of the Scottish Audit of Gastric-Oesophageal Cancer (SAGOC), which did not find a significant relationship between higher hospital volume and reduced inpatient mortality or long-term survival following oesophagectomy and gastrectomy[23]. This discrepancy may lie in the potential advantages and disadvantages of the two studies. Although the data of the present study were collected retrospectively, and misclassification and coding bias remain potential problems, the data are believed to be of high quality[28]. The one significant disadvantage of the present study is that it has not allowed for risk adjustment by case-mix[29]. However, it seems likely that the aging trend of patients would tend to mitigate against reductions in post-operative mortality, suggesting that age-adjustment of cases might result in even greater decreases in mortality over time. In comparison, SAGOC was a 2-year prospective study that involved approximately 1/7th of the patients included in the present analysis. The fluctuating nature of annual mortality rates emphasises the importance of considering mortality data over longer time periods. Secondly, SAGOC considered both elective and emergency procedures whereas we have analysed only elective cases. Data from colorectal cancer studies have shown a reduced risk of peri-operative death for high-volume surgeons when performing elective but not emergency surgery[30].

Future Work: The present study primarily investigated the effect of hospital volume on in-patient mortality. However, to promote ongoing improvement in the care of upper GI cancer patients, further studies to investigate the effect of hospital volume on outcomes other than mortality (e.g. patient satisfaction[31]), or of individual surgeon volume on patient outcome, are required. Furthermore, the development of outcome measures in patients receiving non-operative treatment (e.g. physical activity and quality-of-life[32]) represents another significant gap area. In conclusion, surgically-treated patients with upper GI cancer are likely to fare better if they are managed within high-volume specialist units. These results add to a growing body of evidence supporting specialisation of surgery for upper GI malignancy. This conclusion has major implications for the delivery of cancer services in Scotland and the rest of Europe.

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Authors' Contributions

RJES, RWP, CG, NAS, DHB, OJG and SPB were all involved in data analysis and manuscript preparation. All authors had approval of the final manuscript.

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Conflicts of Interest

There are no competing interests.

Role of the Funding Source

This study was not funded.

Table and Figure Legends

Table 1: The total numbers of resections and post-operative in-hospital deaths, and the average in-hospital mortality rates over the 22-year study period.

Table 2: Post-operative in-hospital mortality rates for elective upper GI cancer resections according to quartile of hospital-year volume. [a] = statistically different from lowest volume quartile, $p<0{\cdot}01$; [b] = statistically different from lowest volume quartile, $p<0{\cdot}001$; [c] = statistically different from second volume quartile, $p<0{\cdot}01$; [d] = statistically different from second volume quartile, $p<0{\cdot}001$.

Figure 1: a) The average procedural volume of hospitals performing elective upper GI cancer resection in Scotland. **b)** The annual percentage of elective upper GI cancer resections performed in the highest-volume quartile of hospital-years.

Figure 2: The average post-operative in-hospital mortality rates of elective upper GI cancer resections over different time periods in Scotland. Data is grouped into 5-yearly averages plus the last 2 years of the study.

Figure 3: Scattergraphs of in-hospital mortality rate against hospital-year volume for **a)** oesophagectomy, **b)** gastrectomy, **c)** hepatectomy, and **d)** pancreatectomy. Red and blue reference lines demonstrate intersection of the described curves

with recommended mortality rates (5% and 10% for oesophagectomy and gastrectomy; 5% for hepatectomy and pancreatectomy). Colour intensity of data points denotes number of ties.

	Resections (n)	Deaths (n)	Mortality Rate (%)
Oesophagectomy	4265	453	10.6
Gastrectomy	4589	423	9.2
Hepatectomy	757	24	3.2
Pancreatectomy	1014	82	8.1

Table 1 - Skipworth

	Quartile	Volume (resections per hospital-year)	Resections (n)	Deaths (n)	Mortality Rate (%)
Oesophagectomy	1st	1 to 2	195	30	15.4
	2nd	3 to 5	477	65	13.6
	3rd	6 to 10	1019	111	11.0
	4th	≥11	2582	247	9.6 [a,c]
Gastrectomy	1st	1 to 3	416	37	8.9
	2nd	4 to 5	678	74	10.9
	3rd	6 to 9	1463	137	9.4
	4th	≥10	2032	175	8.6
Hepatectomy	1st	1	66	4	6.1
	2nd	2	34	4	11.8
	3rd	3 to 6	78	4	5.1
	4th	≥7	579	12	2.1 [d]
Pancreatectomy	1st	1	97	17	17.5
	2nd	2	102	11	10.8
	3rd	3 to 5	133	7	5.3 [a]
	4th	≥6	682	47	6.9 [b]

Figure 1a- Skipworth

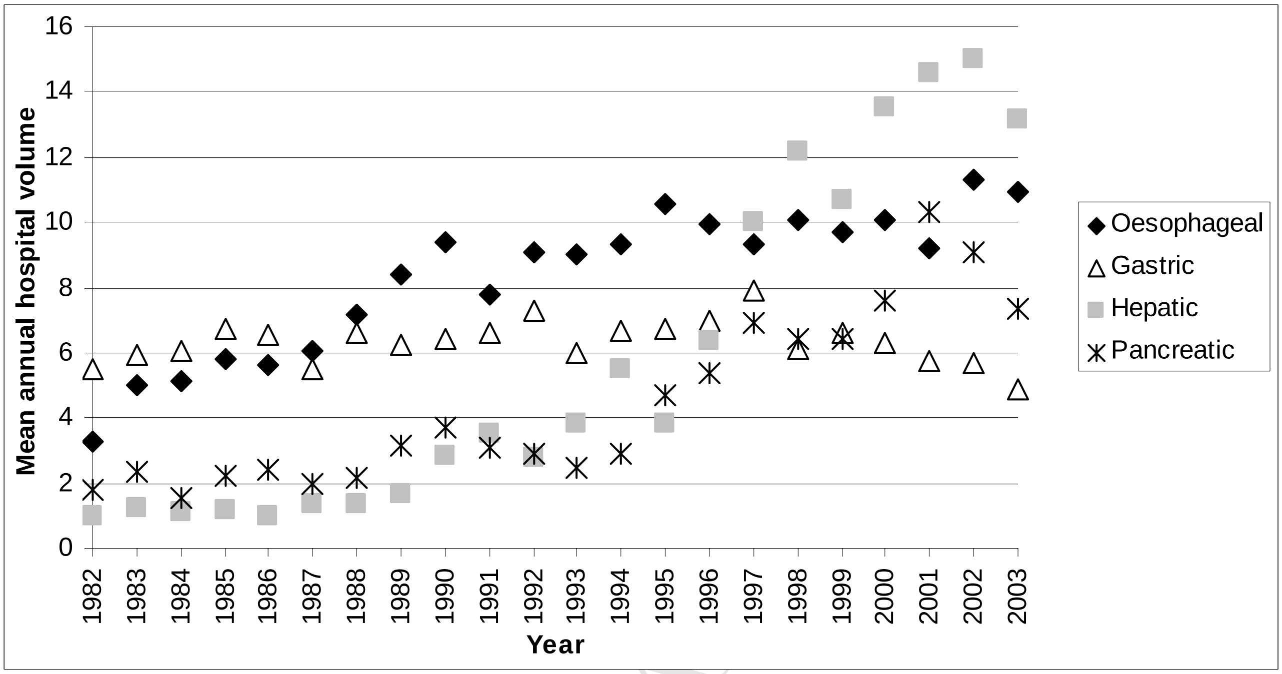


Figure 1b- Skipworth

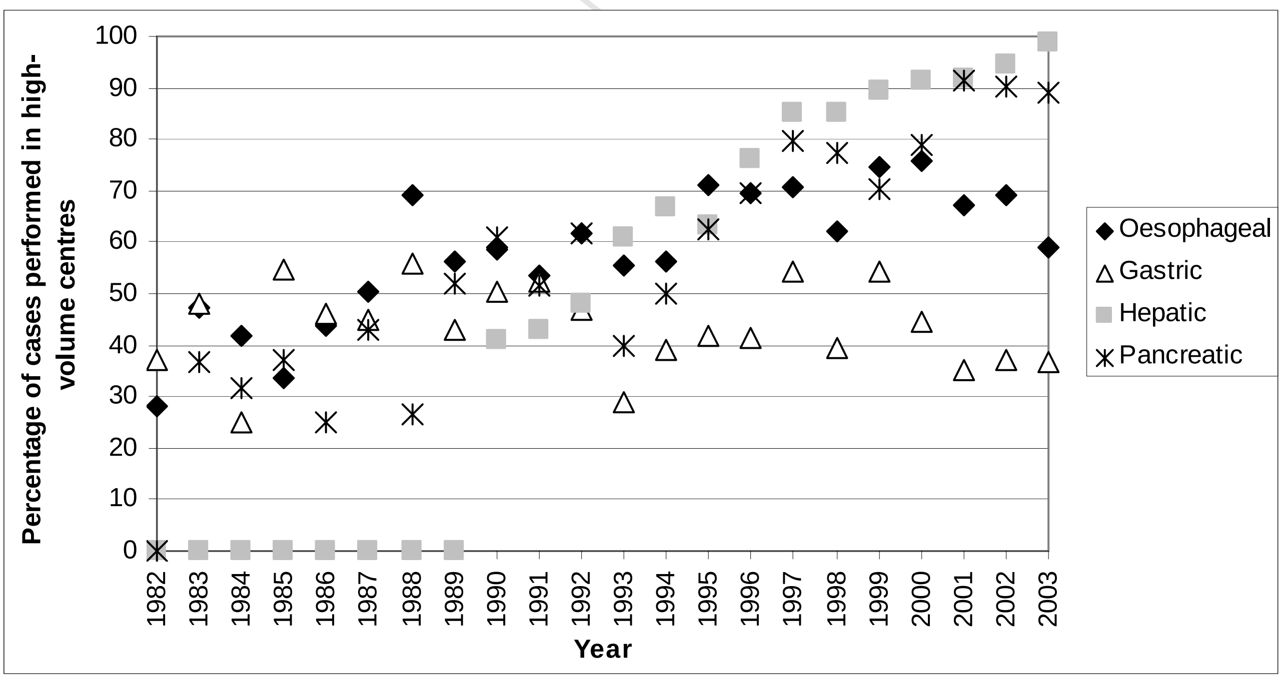
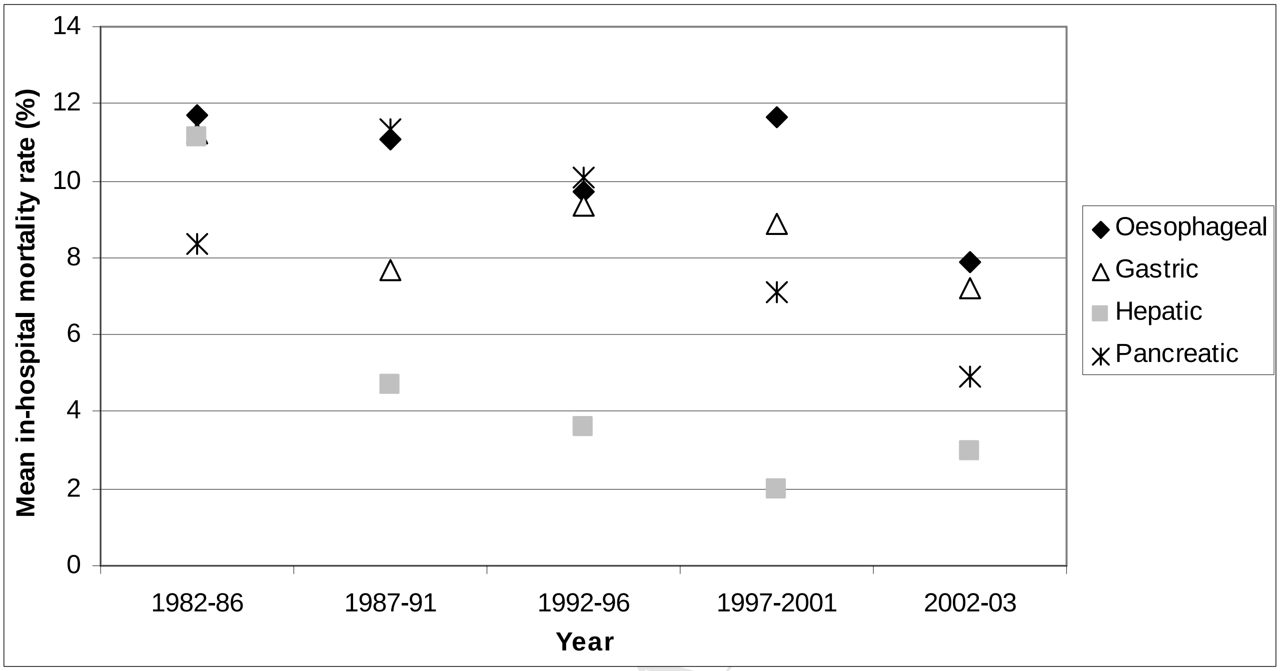


Figure 3 – Skipworth



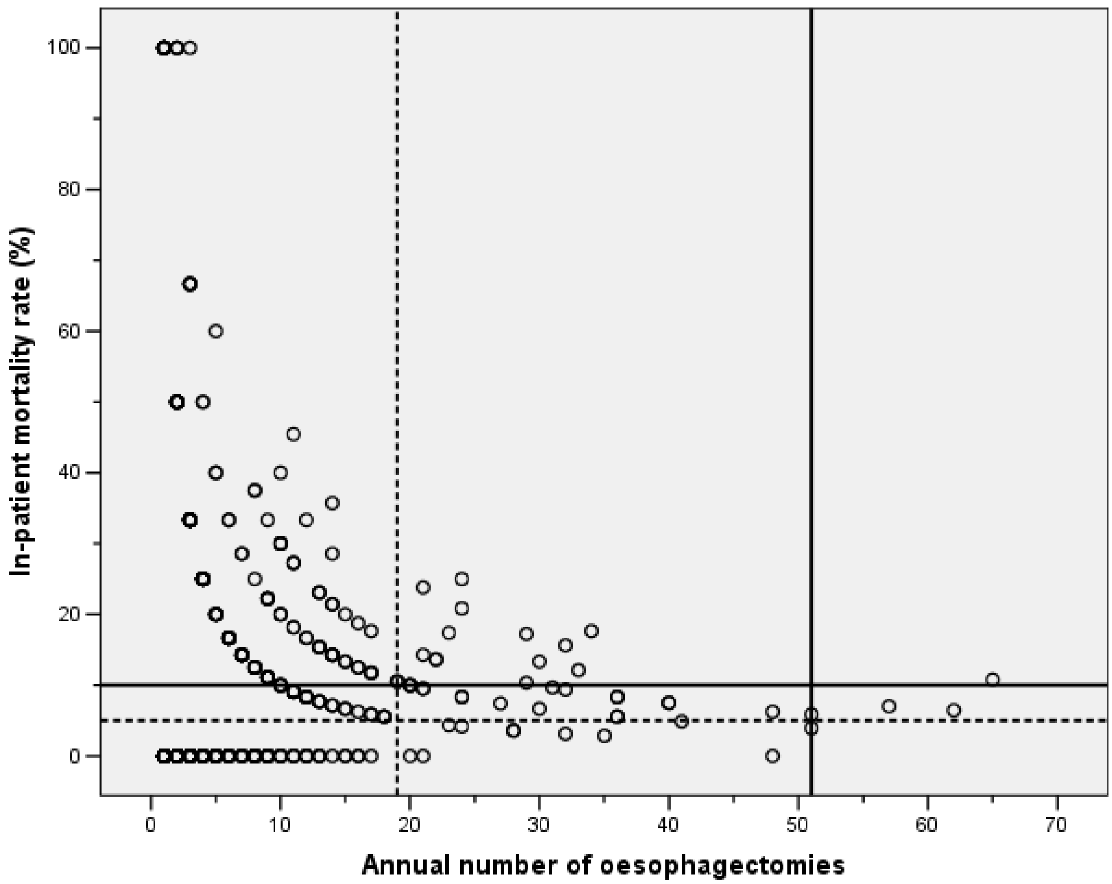


Figure 4a - Skipworth

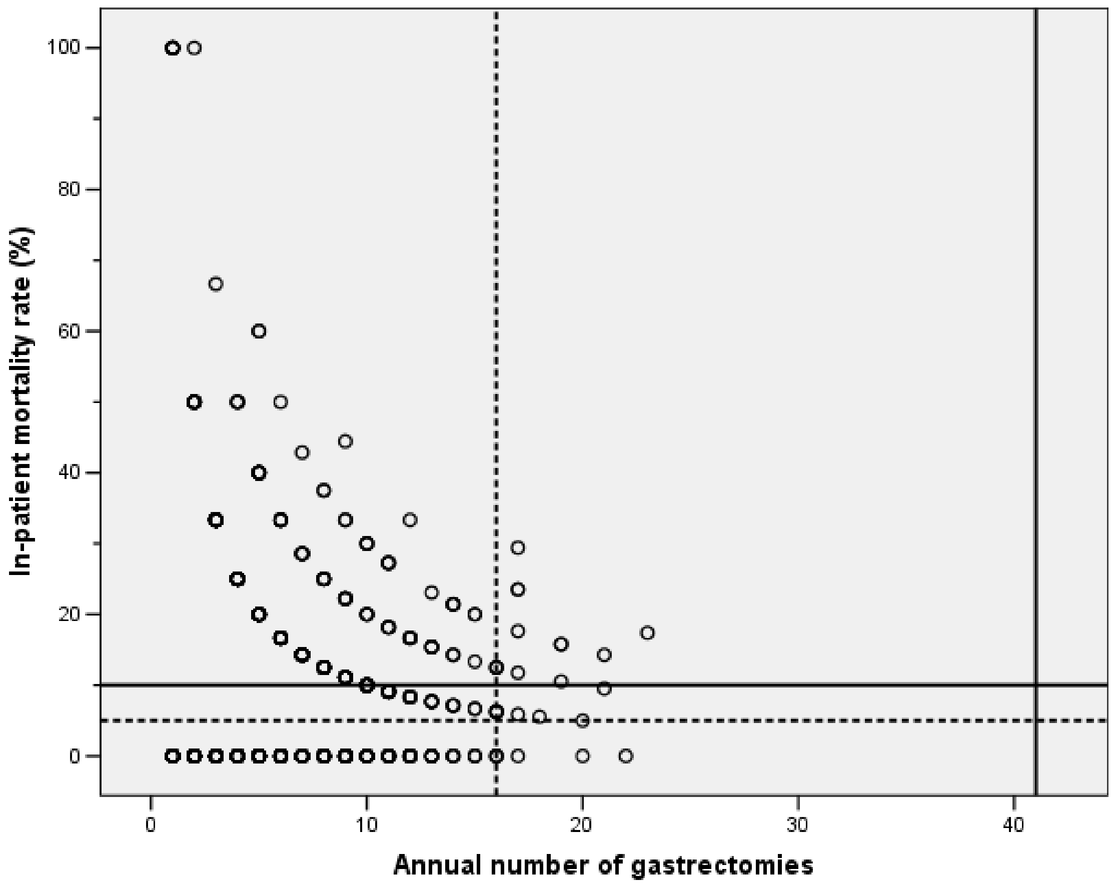


Figure 4b - Skipworth

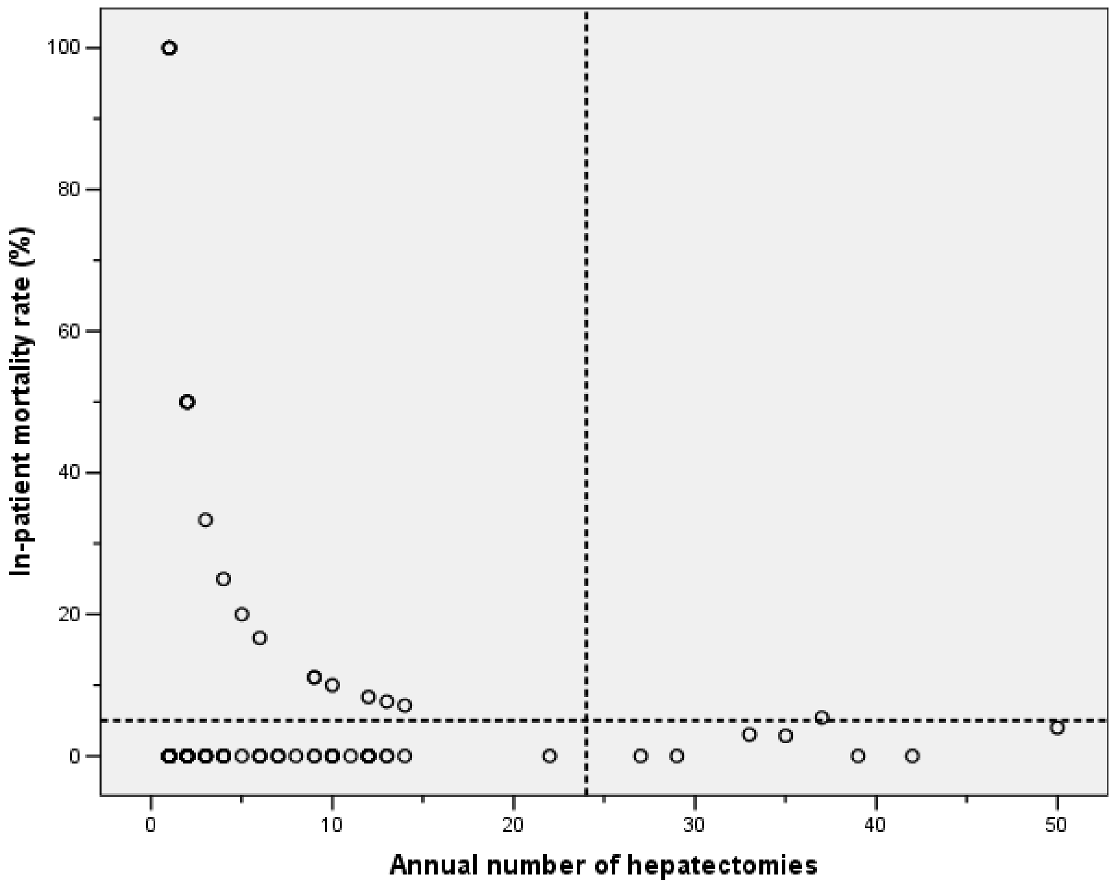


Figure 4c - Skipworth

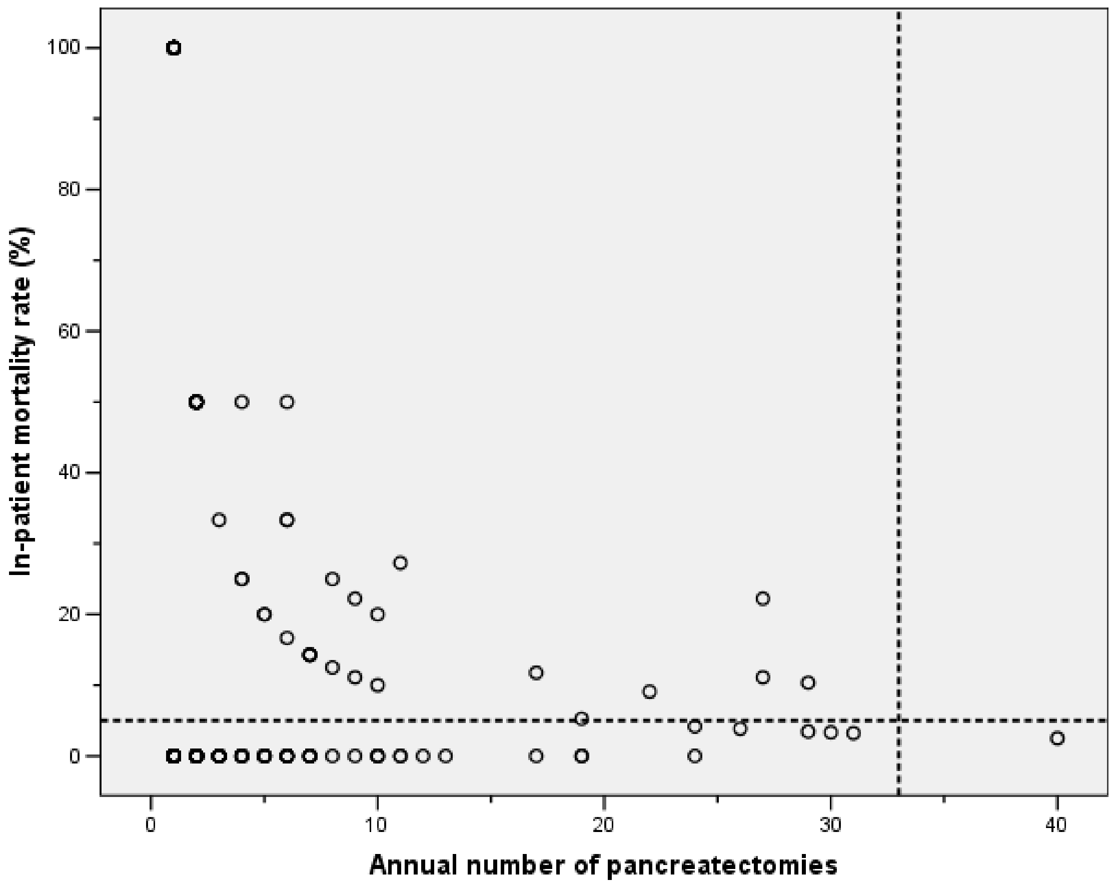


Figure 4d - Skipworth