RURAL, REGIONAL AND REMOTE SURGERY

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# Analysis of surgical mortality in rural South Australia: a review of four major rural hospital in South Australia

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**Key words**
general surgery, hospital mortality, rural population.

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## Abstract

**Background:** One-third of Australia's population reside in rural and remote areas. This audit aims to describe all-causes of mortality in rural general surgical patients, and identify areas of improvement.

**Methods:** This is a retrospective multi-centre study involving four South Australian hospitals (Mt Gambier, Whyalla, Port Augusta, and Port Lincoln). All general surgical inpatients admitted from June 2014 to September 2019 were analysed to identify all-cause of mortality.

**Results:** A total of 80 mortalities were recorded out of 26 996 admissions. The overall mortality rate of 0.3% was the same as the 2020 Victorian state-wide Audit of Surgical Mortality. No mortality was secondary to trauma. Mean age was $79 \pm 11$ years and ASA was $3.9 \pm 1$. Malignancy was associated in over a third of cases (41.2%), mostly colorectal and pancreatic. Most cases were related to general surgical subspecialties: colorectal (51.3%), upper gastrointestinal (21.3%), hepatopancreaticobiliary (13.8%); however, there were also vascular (6.3%) and urology (3.8%) cases. The most common causes of mortality were large bowel obstruction (13.4%), ischemic bowel (10.4%), and small bowel obstruction (7.5%). Majority of mortality were beyond the surgeon's control (73.8%). Of the 21 potentially preventable mortalities, 42.9% were attributed to aspiration pneumonia and decompensated heart failure. Only one (1.3%) mortality case was due to pulmonary embolism.

**Conclusion:** Rural general surgical mortalities occur in older, comorbid patients. Rural surgeons should be equipped to manage basic subspeciality conditions. To further reduce mortalities, clear protocols to prevent aspiration pneumonia and resuscitation associated fluid overload are needed.

## Introduction

According to the Australian Standard Geographical Classification (ASGC), 'rural and remote' is defined as all areas outside of Australia's Major Cities.[1] A third of Australians reside in rural and remote Australia.[2] This demographic exhibit poorer health profiles when compared to the metropolitan cohort, with higher rates of tobacco use, hypertension, obesity, and diabetes.[2,3] Geographic remoteness also results in disparities in quality and accessibility of healthcare.[4,5] The aforementioned barriers result in worse health outcomes and greater all-cause mortality for rural residents.[2,5]

Rural surgeons are challenged to deliver care in resource limited systems for this unique demographic. Therefore, it is paramount for rural surgeons to be aware of causes of mortality and contributing factors. There are few studies describing specific procedural-related mortality in rural surgical patients such as post-emergency laparotomy[6] and post-emergency abdominal surgery.[7] However, there are no comprehensive studies describing all-cause of general surgical mortality in rural Australia. By auditing our five-year experience, this multicenter study aims to fill in the gap in literature by identifying common causes of mortality in rural general surgical patients, and determine areas of improvement to reduce mortality rates.

## Methods

### Data collection

This is a retrospective multicenter cohort study involving four South Australian (SA) hospitals: Mount Gambier (MGH), Whyalla



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(WH), Port Augusta (PAH), and Port Lincoln (PLH) (Fig. 1). We analysed all patients who were admitted to general surgical units between June 2014 and September 2019. All-cause of deaths occurring during hospital stay were recorded, including those that did not receive surgery. Cases were excluded if they were transferred to a metropolitan hospital for management.

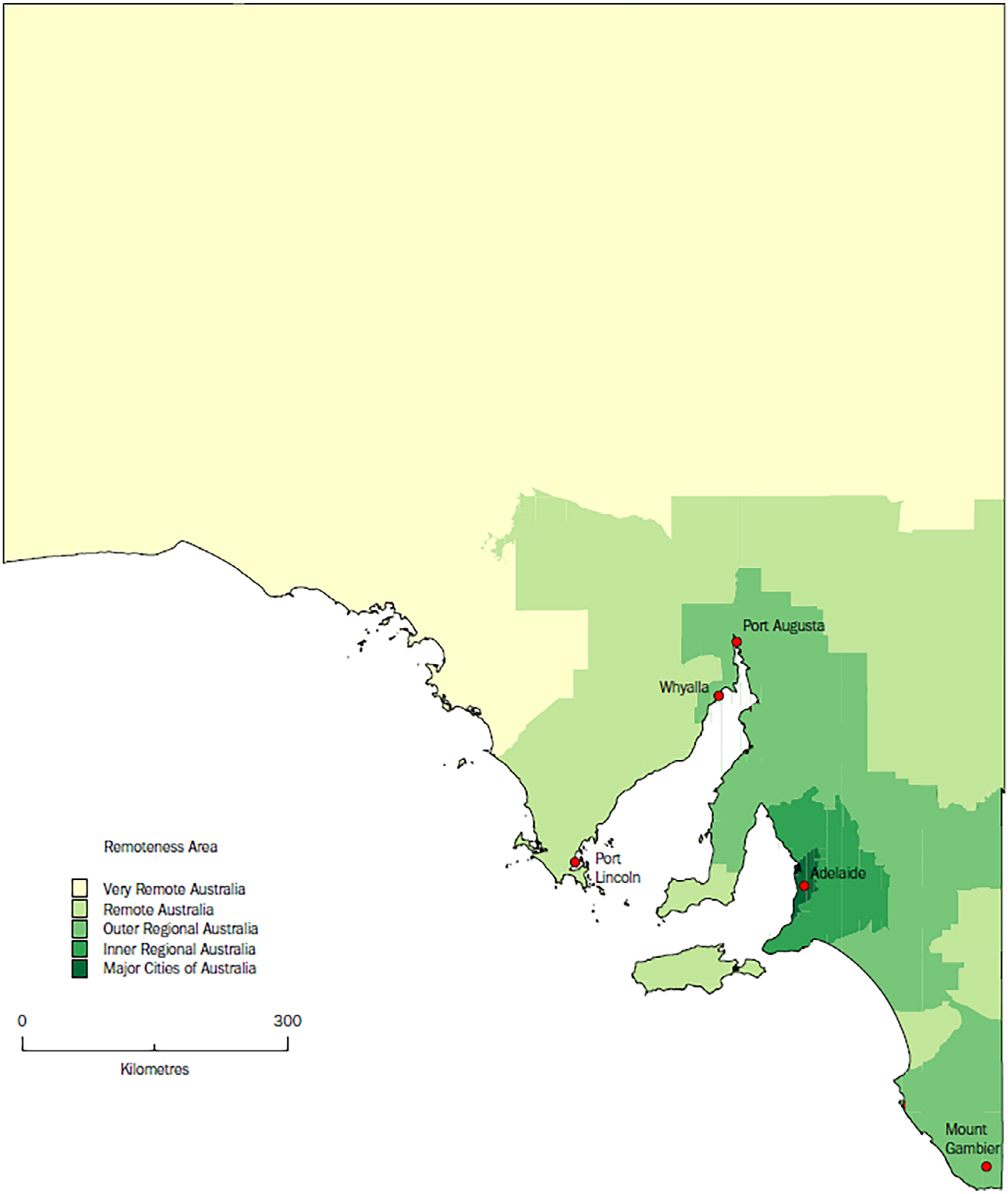


**Fig. 1.** Map of South Australia showing relation of Adelaide to Mt. Gambier, Whyalla, Port Augusta, and Port Lincoln (Based on 2006 Australian standard geographical classification: Remoteness structure).

Mortality cases were identified from six monthly departmental audits that are peer-reviewed at the Department of Surgery, The Queen Elizabeth Hospital. Further patient details were extracted from the online medical records, this includes: gender, age, American Society of Anaesthesiologists (ASA) score, admission type (emergency or elective), primary diagnosis, goals of care, treatment received, length of stay (LOS), and primary cause of death (PCOD). Admissions were considered as emergency when the patient needs to be admitted within 24 h for management.[8]

The International Classification of Diseases and related health problems 10th revision (ICD-10)[9] was used to classify primary diagnosis and PCOD. Primary diagnosis was defined as the medical condition responsible for patient's presentation and admission to hospital. Based on the primary diagnosis, cases were categorized into their surgical subspecialties. Goals of care on admission were divided into palliation, conservative management, and full measures. These were determined upon discussion with the patient, substitute decision maker, or patient's advance care directive. Conservative management was defined as cases that were only for non-operative management (e.g., intravenous antibiotics).

Contributing factors to mortality were categorized into events outside of surgeon's control or potentially modifiable events. Events outside surgeon's control include delayed presentation to hospital, progression of primary diagnosis, and patient declining life-saving treatment. Events possibly within surgeon's control include preoperative missed diagnosis, preoperative decision to operate, medical complication unrelated to primary diagnosis and post-operative complications (medical or surgical).

Statistical analysis was performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Continuous variable statistics were presented as mean ± standard deviation. When analysing between elective and emergency admissions, t-test was employed. Statistical significance was considered when $P$-value was <0.05.

As this project fell under audit and quality assurances, formal ethical review was not required. All data have been managed appropriately under the Australian code of the Responsible Conduct of Research.

## Setting

MGH is a 110-bed hospital located 433 km south-east from Adelaide, serving a population of 27 000.[10,11] WH is a 93-bed hospital located 385 km north-west from Adelaide, serving a population of 24 500.[12,13] PAH is a 82-bed hospital located 310 km north-west from Adelaide, serving a population of 15 800.[14,15] PLH is a 50-bed hospital located 650 km west from Adelaide, serving a population of 20 500.[16,17] Mt. Gambier Hospital has four resident general surgeons and Pt Lincoln one resident surgeon, supported by regular locum support leading to a 1:4 on call roster. The remaining two hospitals have visiting surgeons that rotate weekly from metropolitan South Australia hospitals, on call for 5 days in Whyalla and 7 days in Pt Augusta. All four hospitals have 24-h access to operating theatres, radiology, and consultants providing services such as general medicine, anaesthetics. MGH and WH have a high dependency unit (HDU) with an overlooking consultant physician. None of the hospitals have formal intensive care unit (ICU) on site. Surgical subspecialties and interventional radiology cover are varied and limited by availability of staff. All four hospitals have access to tertiary hospitals if ICU or surgical subspecialties are required.

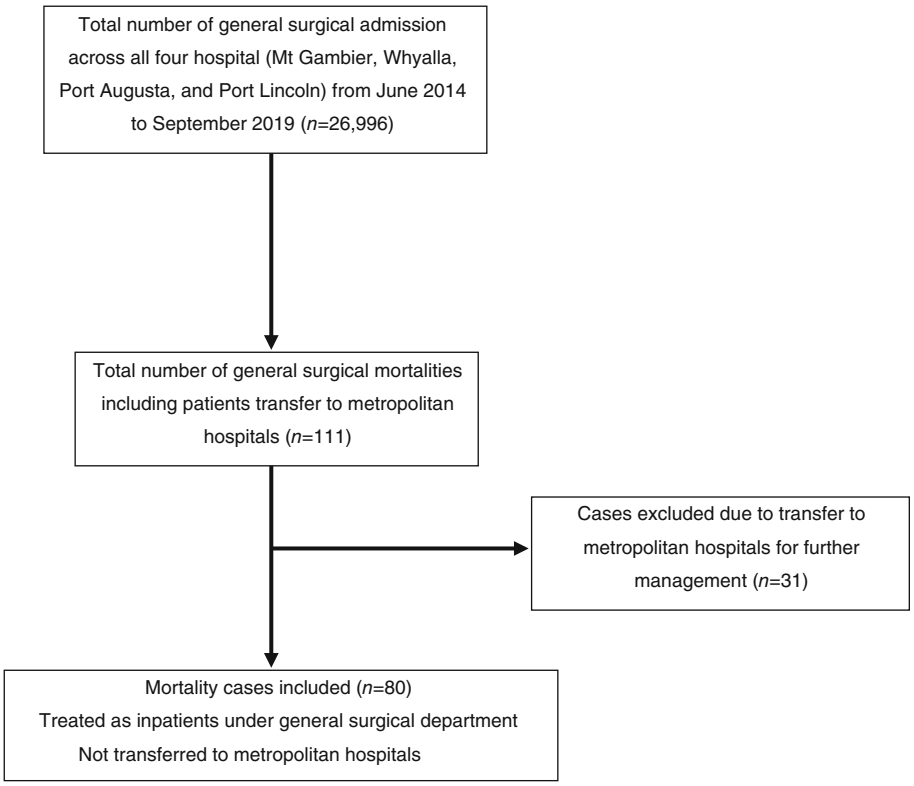


**Fig. 2.** Inclusion and exclusion of patients.

# Results

## All admissions

From June 2014 to September 2019, a total of 26 996 patients were admitted under the general surgical units of the four hospitals. Eighty inpatient mortalities occurred resulting in an overall mortality rate of 0.3% (Fig. 2). None were indigenous patients.

Of the 80 mortalities, 46 (57.5%) were male. The mean age was 79 ± 11.0 years (range 26–97) and mean ASA 3.9 ± 1.0, with no patients determined to have an ASA of 1 (Table 1). Goals of care were palliative in 39 (48.8%) patients, 23 (28.8%) patients were for full measures, and 18 (22.5%) for conservative management. Average LOS was 10.7 ± 8.3 days. Underlying malignancy was associated with 33 mortalities (41.3%).

Colorectal presentations were the most common, 41 (51.3%), with top three diagnoses: large bowel obstruction (LBO) 13 (16.3%), small bowel obstruction (SBO) 9 (11.3%), and ischaemic bowel 6 (7.5%). Followed by Upper gastrointestinal presentations (17 cases, 21.3%), majority of the primary diagnoses were peptic ulcer disease (PUD) ($n = 7$, 8.8%), and gastric outlet obstruction (GOO) ($n = 6$, 7.5%). The third most common presentation was hepatopancreaticobiliary ($n = 11$,13.8%), with the majority being pancreatic cancer ($n = 3$, 3.8%). Vascular conditions accounted for 5 (6.3%) cases, with 3 (3.8%) infected necrotic leg ulcers and 2 (2.5%) ruptured abdominal aortic aneurysms (AAA). There were 3 (3.8%) urological presentations which included prostate cancer, urosepsis and elective orchidectomy for prostate cancer. Gynaecology had two cases (2.5%): one endometrial cancer and one ovarian cancer. One (1.3%) cardiothoracic case, presented with symptomatic malignant pleural effusion secondary to lung metastasis requiring chest drain insertion (Table 2). No mortalities were related to trauma (Table 3).

29 (36.3%) cases underwent surgery, of which, 69.0% were performed open. The most common procedures were bowel resections

**Table 1** Patient mortality demographics and hospitalization details

| | Elective ($n = 13$) | Emergency ($n = 67$) | Total ($n = 80$) | *P*-value |
|---|---|---|---|---|
| Male | 8 | 38 | 46 | 0.757 |
| Female | 5 | 29 | 34 | 0.757 |
| Age (years, mean ± SD) | 74 ± 9.3 | 80 ± 11.2 | 79 ± 11.0 | 0.0670 |
| ASA score | | | | |
| ASA 1 | 0 | 0 | 0 | |
| ASA 2 | 3 (23.1%) | 7 (10.4%) | 10 (12.5%) | 0.338 |
| ASA 3 | 1 (7.7%) | 15 (22.4%) | 16 (20%) | 0.125 |
| ASA 4 | 3 (23.1%) | 26 (38.8%) | 29 (36.2%) | 0.261 |
| ASA 5 | 6 (46.2%) | 19 (28.4%) | 25 (31.3%) | 0.266 |
| ASA (mean ± SD) | 3.9 ± 1.3 | 3.9 ± 1.0 | 3.9 ± 1.0 | 0.847 |
| Goals of care (at time of admission) | | | | |
| Full measures | 1 (7.7%) | 22 (32.8%) | 23 (28.8%) | **0.0143** |
| Non-operative management | 2 (15.4%) | 16 (23.9%) | 18 (22.5%) | 0.475 |
| Palliative | 10 (76.9%) | 29 (43.3%) | 39 (48.8%) | 0.185 |
| Primary diagnosis related to malignancy | 13 (100%) | 20 (29.9%) | 33 (41.3%) | **0.001** |
| Surgical speciality | | | | |
| Colorectal | 2 (15.4%) | 39 (58.2%) | 41 (51.3%) | **0.0019** |
| Upper gastrointestinal | 1 (7.7%) | 16 (23.9%) | 17 (21.3%) | 0.0945 |
| Hepatopancreaticobiliary | 6 (46.2%) | 5 (7.5%) | 11 (13.8%) | **0.0208** |
| Vascular | 0 | 5 (7.5%) | 5 (6.3%) | **0.0242** |
| Urology | 1 (7.7%) | 2 (3.0%) | 3 (3.8%) | 0.564 |
| Gynaeoncology | 2 (15.4%) | 0 | 2 (2.5%) | 0.165 |
| Cardiothoracic | 1 (7.7%) | 0 | 1 (1.3%) | 0.337 |
| Cases that underwent surgery | 3 (23.1%) | 26 (38.8%) | 29 (36.3%) | 0.261 |
| Open | 1 (33.3%) | 19 (73.1%) | 20 (69.0%) | **0.0384** |
| Laparoscopic | 1 (33.3%) | 2 (7.7%) | 3 (10.3%) | 0.564 |
| Endoscopy | 1 (33.3%) | 3 (11.5%) | 4 (14.8%) | 0.697 |
| Convert to open | 0 | 2 (7.7%) | 2 (6.9%) | 0.161 |
| Return to theatre | 0 | 3 (11.5%) | 3 (10.3%) | 0.0832 |
| Length of stay (days, mean ± SD) | 10.7 ± 8.3 | 6.8 ± 7.8 | 7.4 ± 8.0 | 0.135 |
| Mortality rate (denominator being elective/emergency/ overall number of admissions) | 0.07% | 0.7% | 0.3% | **0.0025** |
| Events outside of surgeon's control | | | | |
| Progression of primary diagnosis | 9 (69.2%) | 46 (68.7%) | 55 (68.8%) | 0.950 |
| Patient declining life-saving treatment | 0 | 3 (4.5%) | 3 (3.8%) | 0.0832 |
| Delay presentation to hospital | 0 | 1 (1.5%) | 1 (1.3%) | 0.321 |
| Events possibly within surgeon's control | | | | |
| Post-operative complications (Medical) | 2 (15.4%) | 6 (9.0%) | 8 (10%) | 0.567 |
| Medical complication unrelated to primary diagnosis | 1 (7.7%) | 5 (7.5%) | 6 (7.5%) | 0.978 |
| Post-operative complications (Surgical) | 0 | 5 (7.5%) | 5 (7.5%) | **0.0242** |
| Pre-operative missed diagnosis | 0 | 1 (1.5%) | 1 (1.3%) | 0.321 |
| Pre- operative decision to operate | 1 (7.7%) | 0 | 1 (1.3%) | 0.337 |

*Note*: *P*-value when comparing elective against emergency cases. Significant values are highlighted by bold text. Total number of overall admissions = 26 996. Total number of elective admissions = 17 582. Total number of emergency admissions = 9044.

**Table 2** Primary diagnosis on admission (elective and emergency cases)

| Primary diagnosis on admission (elective cases only) | Number of cases | % of elective cases ($n = 13$) | % of total cases ($n = 80$) |
|---|---|---|---|
| Ascites from peritoneal metastasis | 4 | 30.8 | 5 |
| Colorectal cancer | 2 | 15.4 | 2.5 |
| Hepatic cancer | 2 | 15.4 | 2.5 |
| Oesophageal cancer | 1 | 7.7 | 1.3 |
| Ovarian cancer | 1 | 7.7 | 1.3 |
| Endometrial cancer | 1 | 7.7 | 1.3 |
| Pleural effusion secondary to lung metastasis | 1 | 7.7 | 1.3 |
| Inguinal hernia repair and Orchidectomy—hormonal deprivation of prostate cancer | 1 | 7.7 | 1.3 |
| **Primary diagnosis on admission (emergency cases only)** | **Number of cases** | **% of Emergency cases ($n = 67$)** | **% of total cases ($n = 80$)** |
| Upper gastrointestinal | | | |
| Peptic ulcer disease | 7 | 10.5 | 8.8 |
| Gastric outlet obstruction (GOO) | 6 | 9.0 | 7.5 |
| GOO secondary to gastric cancer | 2 | 3.0 | 2.5 |
| GOO secondary to pancreatic cancer | 2 | 3.0 | 2.5 |
| GOO secondary to cholangiocarcinoma | 1 | 1.5 | 1.3 |
| GOO secondary to unknown cause | 1 | 1.5 | 1.3 |
| Oesophageal varices | 1 | 1.5 | 1.3 |
| Upper GI bleed of unknown cause | 1 | 1.5 | 1.3 |
| Colorectal | | | |
| Large bowel obstruction (LBO) | 13 | 19.4 | 16.3 |
| LBO secondary to colorectal cancer | 7 | 10.5 | 8.8 |
| LBO secondary to unknown cause | 4 | 6.0 | 5.0 |
| LBO secondary to endometrial cancer | 1 | 1.5 | 1.3 |
| LBO secondary to faecal impaction | 1 | 1.5 | 1.3 |
| Small bowel obstruction (SBO) | 8 | 11.9 | 10 |
| SBO secondary to adhesions | 6 | 9.0 | 7.5 |
| SBO secondary to small bowel cancer | 1 | 1.5 | 1.3 |
| SBO secondary to unknown cause | 1 | 1.5 | 1.3 |
| Ischaemic bowel | 6 | 9.0 | 7.5 |
| PR bleeding of unknown cause | 3 | 4.5 | 3.8 |
| Bowel perforation secondary to colorectal cancer | 2 | 3.0 | 2.5 |
| Incarcerated hernia | 2 | 3.0 | 2.5 |
| Perforated diverticulitis | 2 | 3.0 | 2.5 |
| Colonic pseudoobstruction | 1 | 1.5 | 1.3 |
| Sigmoid volvulus | 1 | 1.5 | 1.3 |
| Infective colitis | 1 | 1.5 | 1.3 |
| PR bleeding secondary to malignancy | 1 | 1.5 | 1.3 |
| Metastatic adenocarcinoma of unknown origin | 1 | 1.5 | 1.3 |
| Hepatopancreaticobiliary | | | |
| Acute pancreatitis | 2 | 3.0 | 2.5 |
| Cholecystitis | 2 | 3.0 | 2.5 |
| Choledocholithiasis | 1 | 1.5 | 1.3 |
| Urology | | | |
| Septic shock from urosepsis | 1 | 1.5 | 1.3 |
| Prostate cancer | 1 | 1.5 | 1.3 |
| Vascular | | | |
| Necrotic leg ulcers (arterial/diabetic) | 3 | 4.5 | 3.8 |
| Ruptured AAA | 2 | 3.0 | 2.5 |

(65.5%), and gastroscopy for peptic ulcer disease (10.3%). Only 3 (10.3%) patients required return to theatre: 1 subtotal colectomy for ischaemic bowel post-cholecystectomy, 1 laparotomy and washout of abscess post right hemicolectomy, and 1 arterial repair for haemorrhage post sigmoid colectomy. (Table 4)

Contributing mortality factors outside of surgeon's control included progression of primary diagnosis (68.8%), patient refusal of treatment (3.8%) and delayed presentation to hospital (1.3%). Potentially modifiable events include post-operative complications-medical (10%), medical complication unrelated to primary diagnosis (7.5%), post-operative complications-surgical (7.5%), pre-operative missed diagnosis (1.3%), and pre-operative decision to operate (1.3%). Top PCOD for potentially modifiable events were 4 (5%) decompensated heart failure, 4 (5%) aspiration pneumonia, and 2 (2.5%) cardiac arrest post-operation (Table 5).

## Elective versus emergency admission

Of the 80 mortalities, 13 (16.3%) were elective admissions and 67 (83.8%) were emergency admissions. When considering overall number of admissions (emergency = 9044, elective = 17 952), the mortality rate from emergency admissions was significantly higher when compared to elective admissions (0.7% versus 0.07%; $p < 0.0025$).

**Table 3** Primary cause of death (elective and emergency cases)

| Primary cause of death (elective cases only) | Number of cases | % of elective cases ($n = 13$) | % of total cases ($n = 80$) |
|---|---|---|---|
| Aspiration pneumonia | 2 | 15.4 | 2.5 |
| Oesophageal cancer | 1 | 7.7 | 1.3 |
| Colorectal cancer | 1 | 7.7 | 1.3 |
| Pancreatic cancer | 1 | 7.7 | 1.3 |
| Hepatic cancer | 1 | 7.7 | 1.3 |
| Ovarian cancer | 1 | 7.7 | 1.3 |
| Endometrial cancer | 1 | 7.7 | 1.3 |
| Pleural effusion secondary to lung metastasis | 1 | 7.7 | 1.3 |
| Pulmonary oedema secondary to acute on chronic renal failure | 1 | 7.7 | 1.3 |
| Small bowel obstruction | 1 | 7.7 | 1.3 |
| Upper GI bleed of unknown cause | 1 | 7.7 | 1.3 |
| **Primary cause of death (emergency cases only)** | **Number of cases** | **% of Emergency cases ($n = 67$)** | **% of total cases ($n = 80$)** |
| Upper gastrointestinal | | | |
| Peptic ulcer disease | 4 | 6.0 | 5.0 |
| Gastric outlet obstruction (GOO) - gastric cancer | 1 | 1.5 | 1.3 |
| Gastric cancer | 1 | 1.5 | 1.3 |
| Small bowel cancer | 1 | 1.5 | 1.3 |
| Haemorrhagic shock from oesophageal varices | 1 | 1.5 | 1.3 |
| Colorectal | | | |
| Large bowel obstruction | 9 | 13.4 | 11.3 |
| LBO secondary to unknown cause | 4 | 6.0 | 5.0 |
| LBO secondary to colorectal cancer | 3 | 4.5 | 3.8 |
| LBO secondary to endometrial cancer | 1 | 1.5 | 1.3 |
| LBO secondary to stomal stricture | 1 | 1.5 | 1.3 |
| Ischaemic bowel | 7 | 10.4 | 8.8 |
| Small bowel obstruction (SBO)—adhesions | 5 | 7.5 | 6.3 |
| Colorectal cancer | 2 | 3.0 | 2.5 |
| Bowel perforation—secondary to colorectal cancer | 2 | 3.0 | 2.5 |
| Metastatic adenocarcinoma of unknown origin | 2 | 3.0 | 2.5 |
| Colonic pseudoobstruction | 1 | 1.5 | 1.3 |
| Septic shock secondary to infective colitis | 1 | 1.5 | 1.3 |
| Perforated diverticulitis | 1 | 1.5 | 1.3 |
| Haemorrhagic shock from lower GI bleed of unknown cause | 1 | 1.5 | 1.3 |
| Recurrent Intra-abdominal abscess | 1 | 1.5 | 1.3 |
| Hepatopancreaticobiliary | | | |
| Septic shock secondary to ascending cholangitis | 2 | 3.0 | 2.5 |
| Subphrenic collection secondary to acute cholecystitis | 1 | 1.5 | 1.3 |
| Acute pancreatitis | 1 | 1.5 | 1.3 |
| Cholangiocarcinoma | 1 | 1.5 | 1.3 |
| Urology | | | |
| Septic shock from urosepsis | 1 | 1.5 | 1.3 |
| Prostate cancer | 1 | 1.5 | 1.3 |
| Vascular | | | |
| Septic shock from necrotic leg ulcers (arterial/diabetic) | 3 | 4.5 | 3.8 |
| Ruptured AAA | 2 | 3.0 | 2.5 |
| Cardiology | | | |
| Decompensated heart failure | 4 | 6.0 | 5.0 |
| Cardiac arrest | 3 | 4.5 | 3.8 |
| Myocardial infarction secondary to rapid A-fib post-op | 1 | 1.5 | 1.3 |
| Haemorrhagic shock | 1 | 1.5 | 1.3 |
| Pulmonary | | | |
| Aspiration pneumonia | 3 | 4.5 | 3.8 |
| Hospital acquired pneumonia | 1 | 1.5 | 1.3 |
| Pulmonary embolism | 1 | 1.5 | 1.3 |
| Neurological | | | |
| Ischaemic stroke | 1 | 1.5 | 1.3 |

Between elective and emergency admissions, there were no statistically significant differences in gender, age, ASA score, admissions requiring surgery, unplanned returns to theatre or LOS. Documented goals of care for full treatment measures in emergency admissions were significantly greater than in elective admissions (32.8% versus 7.7%; $p < 0.0143$). Elective cases had significantly

**Table 4** Mortality cases associated with surgery

| | Sex | Age (range) | ASA[†] | Primary diagnosis | Surgery | Return to theatre | Primary cause of death |
|---|---|---|---|---|---|---|---|
| Elective | M | 61–70 | 5 | Pancreatic cancer—Peritoneal Metastases causing ascities | Endoscopic insertion of gastrostomy tube | NO | Aspiration pneumonia |
| | M | 71–80 | 2 | Colorectal cancer | Laparoscopic right hemicolectomy | NO | Aspiration pneumonia |
| | M | 81–90 | 3 | Inguinal hernia repair and orchidectomy—hormonal deprivation of prostate cancer | Open orchidectomy | NO | Pulmonary oedema |
| Emergency | M | 21–30 | 2 | Cholecystitis | Lap converted to open cholecystectomy | Open subtotal colectomy for ischaemic bowel | Cardiac arrest |
| | M | 61–70 | 5 | Ischaemic bowel | Exploratory laparotomy | NO | Ischaemic bowel |
| | M | | 4 | Necrotic diabetic foot ulcer | Open ulcer debridement | NO | Septic shock |
| | M | 71–80 | 3 | SBO[¶]—Metastatic adenocarcinoma of unknown origin | Open adhesiolysis and small bowel resection with primary anastomosis. | NO | Metastatic adenocarcinoma of unknown origin |
| | M | | 2 | Ischaemic bowel | Exploratory laparotomy | NO | Ischaemic bowel |
| | F | | 2 | LBO—Colorectal cancer | Right hemicolectomy and colorectal cancer debulking | Laparotomy and washout | Recurrent postoperative abscess |
| | M | | 3 | Incarcerated hernia | Open hernia repair | NO | Cardiac arrest |
| | M | | 5 | GOO—Gastric cancer | Open palliative gastroenterostomy | NO | Gastric cancer |
| | M | 81–90 | 3 | Choledocholithiasis | Laparoscopic cholecystostomy | NO | Ascending cholangitis |
| | M | | 4 | GOO[‡]—Cholangiocarcinoma | Open palliative gastroenterostomy | NO | Cholangiocarcinoma |
| | F | | 2 | GOO—Pancreatic cancer | Open Hartmann's procedure and palliative gastroenterostomy | NO | LBO[§] secondary to stomal stricture |
| | M | | 4 | GOO—Pancreatic cancer | Open palliative gastroenterostomy | NO | Ascending cholangitis |
| | F | | 4 | Incarcerated hernia | Open hernia repair | NO | Ischaemic bowel |
| | F | | 3 | Ischaemic bowel | Exploratory laparotomy | NO | Ischaemic bowel |
| | F | | 2 | LBO—Colorectal cancer | Open extended right Hemicolectomy | NO | Haemorrhagic shock |
| | M | | 4 | LBO—Colorectal cancer | Open palliative defunctioning stoma | NO | Colorectal cancer |
| | M | | 5 | LBO—Colorectal cancer | Open palliative defunctioning stoma | NO | Colorectal cancer |
| | M | | 5 | LBO—Faecal impaction | Open caecostomy and decompression | NO | Hospital acquired pneumonia |
| | M | | 4 | Perforated diverticulitis | Open Hartmann's procedure | NO | Myocardial infarction secondary to atrial fibrillation |
| | M | | 3 | PUD[‖] | Gastroscopy | NO | pulmonary oedema |
| | F | | 4 | PUD | Gastroscopy | NO | Ischaemic stroke |
| | M | | 5 | PUD | Gastroscopy | NO | Cardiac arrest |
| | F | | 3 | SBO—Adhesions | Open gastroenterostomy | NO | Aspiration pneumonia |
| | M | | 3 | SBO—Small bowel cancer | Open small bowel resection | NO | Small bowel cancer |
| | M | | 5 | Sigmoid volvulus | Lap converted to open sigmoid colectomy with end colostomy | Laparotomy arterial repair | Aspiration pneumonia |
| | F | 91–100 | 5 | PUD | Laparoscopic omental patch | NO | PUD—Perforated |

[†]ASA: American Society of Anaesthesiologists.

[‡]GOO: Gastric outlet obstruction.

[§]LBO: Large bowel obstruction.

[‖]PUD: Peptic ulcer disease.

[¶]SBO: Small bowel obstruction.

**Table 5** Events possibly modifiable by surgeon (preoperative missed diagnosis, preoperative decision to operate, medical complication unrelated to primary diagnosis, post-operative complications (medical or surgical))

| | Sex | Age (range) | ASA[†] | Primary diagnosis | Treatment received | Primary cause of death |
|---|---|---|---|---|---|---|
| Pre-op missed diagnosis | M | 61–70 | 4 | Ruptured AAA[‡] presenting as leg pain | Initially misdiagnosed and discharged home. Returned with worsening pain | Ruptured AAA |
| Pre-op decision to operate | M | 81–90 | 3 | Inguinal hernia repair and orchidectomy—hormonal deprivation of prostate cancer | Elective orchidectomy | Pulmonary oedema |
| Medical complication unrelated to primary diagnosis | M | 71–80 | 5 | Ascites from peritoneal metastasis from pancreatic cancer | Therapeutic ascitic tap | Upper gastrointestinal bleed from unknown cause |
| | M | | 4 | Acute pancreatitis | Conservative management | Decompensated heart failure |
| | M | 81–90 | 3 | PUD[§] | Transfused with red blood cells | Decompensated heart failure |
| | F | | 4 | Upper gastrointestinal bleed from unknown cause | Conservative management | Decompensated heart failure |
| | M | | 4 | Upper gastrointestinal bleed from unknown cause | Conservative management | Decompensated heart failure |
| | F | | 3 | Upper gastrointestinal bleed from unknown cause | Transfused with Red blood cells | Pulmonary embolism |
| Post-op complications (Medical) | M | 21–30 | 2 | Cholecystitis | Open subtotal colectomy for operative ischaemic bowel perforation | Cardiac arrest post-operation |
| | M | 61–70 | 5 | Ascites from peritoneal metastasis from pancreatic cancer | Therapeutic ascitic tap and endoscopic feeding tube placement | Aspiration pneumonia |
| | M | 71–80 | 2 | Colorectal cancer | Elective laparoscopic right hemicolectomy | Aspiration pneumonia |
| | M | | 3 | Incarcerated hernia | Open inguinal repair | Cardiac arrest post-operation |
| | M | 81–90 | 5 | Sigmoid volvulus | Sigmoid colectomy with end colostomy | Aspiration pneumonia |
| | F | | 3 | SBO[‖] secondary to adhesions | Gastro-enterostomy | Aspiration pneumonia |
| | M | | 5 | LBO[¶] secondary to feacal impaction | Open caecostomy + decompression | Hospital acquired pneumonia |
| | M | | 4 | Perforated diverticulitis | IV Abx + Hartmann's procedure | Myocardial infarction secondary to atrial fibrillation |
| Post-op complications (Surgical) | F | 71–80 | 2 | LBO—colorectal cancer | Right hemicolectomy + tumour debulking | Recurrent postoperative abscess |
| | F | 81–90 | 2 | GOO[††]—Pancreatic cancer | Open Hartmann's procedure and palliative gastroenterostomy | LBO secondary to stomal stricture |
| | M | | 4 | GOO—Pancreatic cancer | Open palliative gastroenterostomy | Septic shock secondary to post-operative ascending cholangitis |
| | F | | 4 | Incarcerated hernia | Open hernia repair | Ischaemic bowel |
| | F | | 2 | LBO—Colorectal cancer | Open extended right hemicolectomy | Post-operative haemorrhagic shock |

[†]ASA: American Society of Anaesthesiologists.

[‡]AAA: Abdominal aortic aneurysm.

[§]PUD: Peptic ulcer disease.

[‖]SBO: Small bowel obstruction.

[¶]LBO: Large bowel obstruction.

[††]GOO: Gastric outlet obstruction.

more primary diagnosis related to malignancy (100% versus 29.9%; $p < 0.001$). Emergency admission also had significantly more colorectal (58.2% versus 15.4%; $p < 0.0019$) and more vascular cases (7.5% versus 0%; $p < 0.0170$).

When compared to elective admissions, emergency admissions who underwent surgery were more likely to have an open procedure (73.1% versus 33.3%; $p < 0.05$) and experience fatal post-operative surgical complications (7.5% versus 0%; $p < 0.05$).

## Discussion

To our knowledge, this is the first multi-center study describing all-cause mortality of general surgical patients in rural Australia. The

mean age of 79 ± 11.0 years in this audit resembles the average life expectancy in rural Australia.[18] Additionally, the overall mortality rate (0.3%) was comparable to the 2020 Victorian statewide Audit of Surgical Mortality (VASM).[19]

None of the mortalities were due to trauma. This may reflect the effectiveness of our trauma service in South Australia. Patients with significant trauma in the rural setting are transferred to our metropolitan trauma center (The Royal Adelaide Hospital) via South Australia's medical retrieval service MedSTAR. We acknowledge possible mortalities at the scene of accident, however, data was not available for analysis.

Pulmonary embolism related mortality (1.3%) were significantly lower than previous national studies (10%).[20] It is worth noting previous national studies include patients from other non-surgical specialties. During admission, all patients are considered for mechanical and/or pharmacological thromboprophylaxis.

According to AIHW, top rural general surgery related deaths were related to colorectal cancer followed by prostate cancer. Of the 33 (41.2%) malignancies in this audit, the majority were colorectal cancers 12(36.4%) which is consistent with AIHW's finding. However, in our audit pancreatic cancer 6(18.2%) was the second most common as compared to prostate cancer which only accounted for 2(6.1%). This may be because prostate cancer tends to manifest as non-general surgical complications such as bone fractures, spinal cord compressions, or coagulopathy.[21] This audit found that rural surgery mortality had a higher proportion of cases with malignancy as a comorbidity as compared to the 20.4% identified in the VASM.[19]

This audit highlights the importance for a rural general surgeon in having broad-based knowledge across several surgical specialties, especially relating to acute surgical presentations. Rural surgeons are more likely to encounter surgical pathologies that a metropolitan general surgeon may not where services specialist surgical subspecialties are more easily accessible. For example, patients with end stage prostate cancer can present with hematuria and acute urinary retention or patients presenting with necrotic leg ulcers secondary to peripheral vascular disease would have been admitted under urology and vascular surgery units respectively in a metropolitan hospital.

Of the 21 (26.3%) potentially modifiable mortalities, one (1.3%) was due to a preoperative decision to operate (see Table 5). This involved a male patient in his late 80s who presented for an elective hernia repair for a large irreducible right inguinal hernia and orchidectomy for androgen deprivation of metastatic prostate cancer. Post-operatively the patient developed acute pulmonary oedema secondary to fluid overload due to acute on chronic renal failure.

One case (1.3%) was due to pre-operative missed diagnosis where a male between 61 and 70 years old with dementia and known abdominal aortic aneurysm (AAA) presented to the emergency department with leg pain and was discharged home with analgesia. The patient represented on the same day with new abdominal pain and was found to have a ruptured AAA. This case highlights the need to consider atypical presentations of AAA. A meta-analysis found that up to 51% ruptured AAA present with atypical symptoms (not abdominal pain).[22–24]

In this audit, aspiration pneumonia and decompensated heart failure due to iatrogenic fluid overload make up 42.9% of potentially preventable mortalities. Prevention of these complications is paramount as older patients have limited reserves for recovery. Aspiration pneumonia risk assessment tools and precaution protocol should be implemented to minimize these occurrences.[25–27] This include identifying at-risk patients, such as reduced consciousness, slowed gastric emptying, or obstructed bowel. Aspiration precaution protocol should be initiated if patient is at-risk, and oral intake restricted until a speech pathologist review. Aspiration precaution protocols involve placing swallowing precaution sign above patent's bed, maintaining head of bed above 45°, and ensuring availability of suction equipment.

In the elderly, acute pulmonary oedema can be precipitated by overzealous intra-venous fluid administration.[28] Fluid overload is shown to increase mortality independent of initial disease severity.[29] Therefore, the importance of judicious fluid prescription must be recognized and be dependent on personalized patient requirements. First, identify at-risk patients (i.e. older patients, male, history of heart failure, hypertension, ischemic heart disease or myocardial infarction).[30] Second, implement preemptive fluid strategies which involve the following principles: using dynamic preload markers (pulse pressure variation) in addition to clinical assessment to decide fluid boluses, consider early use of diuretics when resuscitation goals were met and urinary output was less than 0.5 ml/kg/h, and preparation of intravenous medication in concentrated forms by using minimal solvents as possible.[31]

We acknowledge that there are limitations to our study such as its retrospective nature. Second, this study was based on the South Australian rural setting and may not be representative of rural settings in other countries or other parts of Australia. Additionally, data regarding mortalities after transfer to metropolitan hospitals were not available due to lack of access to their medical records. Although this leads to a less comprehensive study, this has allowed us to focus on the mortalities that occurred in a rural setting. Inclusion of mortalities that happened after transfer to a metropolitan hospital would have diluted the accuracy of this paper as metropolitan hospital which have more resources available.

## Conclusion

Rural surgical mortalities were similar to metropolitan hospital mortalities in terms of tendency to occur in older and comorbid patients. However, rural surgical mortalities are more commonly associated with underlying malignancy. Although general surgical conditions are most common, rural surgeons should be equipped to manage acute presentations across different surgical specialties. To further minimize mortalities, aspiration pneumonia and resuscitation associated fluid overload prevention protocols should be implemented.

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## Conflict of interest

None declared.

## Ethical approval

As this project was deemed to fall under audit and quality assurances, formal ethical review was not required. All data have been managed appropriately under the Australian code of the Responsible Conduct of Research.

## Author contributions

**Jianliang Liu:** Conceptualization; data curation; formal analysis; methodology; project administration. **Ying Yang Ting:** Supervision; writing – original draft; writing – review and editing. **Markus Trochsler:** Methodology; supervision; validation; visualization; writing – original draft; writing – review and editing. **Jessica Reid:** Methodology; supervision; visualization; writing – original draft; writing – review and editing. **Adrian Anthony:** Conceptualization; supervision; writing – original draft; writing – review and editing. **Guy Maddern:** Conceptualization; data curation; project administration; validation; visualization; writing – original draft; writing – review and editing.

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