Impact of the Acute Surgical Unit on a Local and Global Scale

Submitted by

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Published Works

Eight peer-reviewed journal articles were published during candidature 2018-2022.

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Kinnear N, Bramwell E, Frazzetto A, Noll A, Patel P, Hennessey D, Otto G, Dobbins C, Sammour T, Moore J. The acute surgical unit improves outcomes in appendicectomy. ANZ J Surg. 2019;89(9):1108-13.

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Thesis Abstract

Introduction

Traditionally, general surgical departments allocated their staff to elective operative and outpatient commitments, with emergency general surgical (EGS) patients managed ad-hoc. An acute surgical unit (ASU) model was pioneered in 1996 and spread globally. However, uptake remains slow, in part due to clinical equipoise. This thesis aims to address key gaps in the literature, to support hospitals considering establishing an ASU and EGS policymakers.

Methods

Locally, three retrospective studies were performed at the Lyell McEwin Health Service. For patients with appendicitis or cholecystitis, these compared cohorts ≤2.5 years pre/post ASU introduction. Primary outcomes were length of stay, time to theatre, after-hours operating rates, rates of cholecystectomy on index admission and rates of appropriate communication and management of incidental pathology (appendicitis patients only). A fourth study prospectively assessed patient reported outcomes within the Royal Adelaide Hospital ASU. Primary outcomes were factors associated with patient satisfaction on multivariate analysis. Nationally, two studies reported the results of a cross-sectional assessment of the general surgery departments in all medium-large sized Australian public hospitals. Primary outcomes were the spectrum of EGS models in use, staff satisfaction and operative exposure. Globally, two systematic reviews were performed. The first identified ASU-type dedicated models of care for emergency patients in urology. The primary outcome was the spectrum of models. The second collated for meta-analysis general surgery studies comparing the Traditional and ASU models. Primary outcomes were length of stay, cost and rates of after-hours operating and complications.

Results

Locally, single centre retrospective studies of 319–1,214 patients found that establishing an ASU was associated with reduced time to theatre and rates of after-hours operating, and superior rates of cholecystectomy on index admission. Length of stay was reduced for patients with cholecystitis but not appendicitis. For presumed-appendicitis patients with incidental pathology, rates of communication or appropriate management were unchanged. Nationally, the cross-sectional study enrolled 119/120 eligible hospitals. Sixty-four (54%) hospitals reported using an ASU or hybrid EGS model. Compared with the Traditional structure, hybrid or ASU models were associated with greater surgeon and registrar satisfaction. Registrar-perceived operating exposure was unaffected by EGS model. Globally, the first systematic review identified seven centres implementing a variety of dedicated models for emergency urological patients. The second review enrolled 77 publications representing 150,981 unique EGS patients from thirteen nations. Compared with the Traditional model, ASU introduction was associated with reductions in length of stay and rates of after-hours operating and complications. Financial assessments found the ASU to deliver equivalence or cost savings.

Conclusion

Compared with the Traditional structure, the ASU model delivers superior outcomes. The ASU model should be promoted in health policy to benefit patients, staff and health budgets. Further improvements may involve ASU wards as centres of

education and excellence, linked contractual obligation and increased funding for general surgeons to deliver EGS care and greater inter-hospital coordination. Future research includes cost analyses, quality improvement initiatives measured by patient reported outcomes and assessment of ASU model utility in other surgical specialties and in low-income countries.

Statement of Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

Signature

Date: 28/01/2022

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Presentations and Scholarships

Presentations

Components of this thesis were presented at:

2019 RACS annual scientific meeting, Bangkok, Thailand

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2019 General Surgeons Australia annual scientific meeting, Hobart

2019 USANZ SA section meeting, Adelaide

2019 Provincial Surgeons of Australia annual scientific conference, Ballarat

2019 14th Asia-Pacific Congress of Endoscopic & Laparoscopic Surgery of Asia, Chiang Mai, Thailand

2019 ACEM annual scientific meeting, Hobart

2020 Urological Society of ANZ annual scientific meeting, Sydney

2020 RACS annual scientific meeting, Melbourne

2020 University of Adelaide FHMS Florey post-graduate research conference

2020 RACS Victorian committee annual scientific research awards, Melbourne

2021 RACS annual scientific meeting, Melbourne

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2020	RACS Brendan Dooley/ Gordon Trinca trauma research scholarship	\$10,000

Abbreviations

ACEM: Australasian College for Emergency Medicine

FHMS: Faculty of Health and Medical Sciences

NHMRC: National Health & Medical Research Council

NT: Northern Territory

RACS: Royal Australasian College of Surgeons

SA: South Australia

USANZ: Urological Society of Australia and New Zealand

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Chapter 1: Introduction

The Problem

Optimal allocation of resources to care for both elective and emergency general surgical (EGS) patients has long been a challenge. Ideally the healthcare sector would be able to deliver timely care with the appropriate suite of assets to both categories of patients without wastage. Unfortunately, this goal is made difficult due to variations in funding, workforce and most of all the number and needs of the emergency patients (1). Historically, general surgery departments have managed patients within the 'Traditional' model. All surgeons and doctors in training were allocated in-hours to outpatient clinics and elective operating lists. On-call rosters were superimposed on top of this and rotated between general surgical units and their staff. Unplanned EGS patients with conditions such as appendicitis were treated as circumstances dictated. Most emergency surgery was delayed until after-hours when elective operating had completed, while life- or limb-threatening conditions were dealt with immediately, through the deferral or cancellation of elective patients.

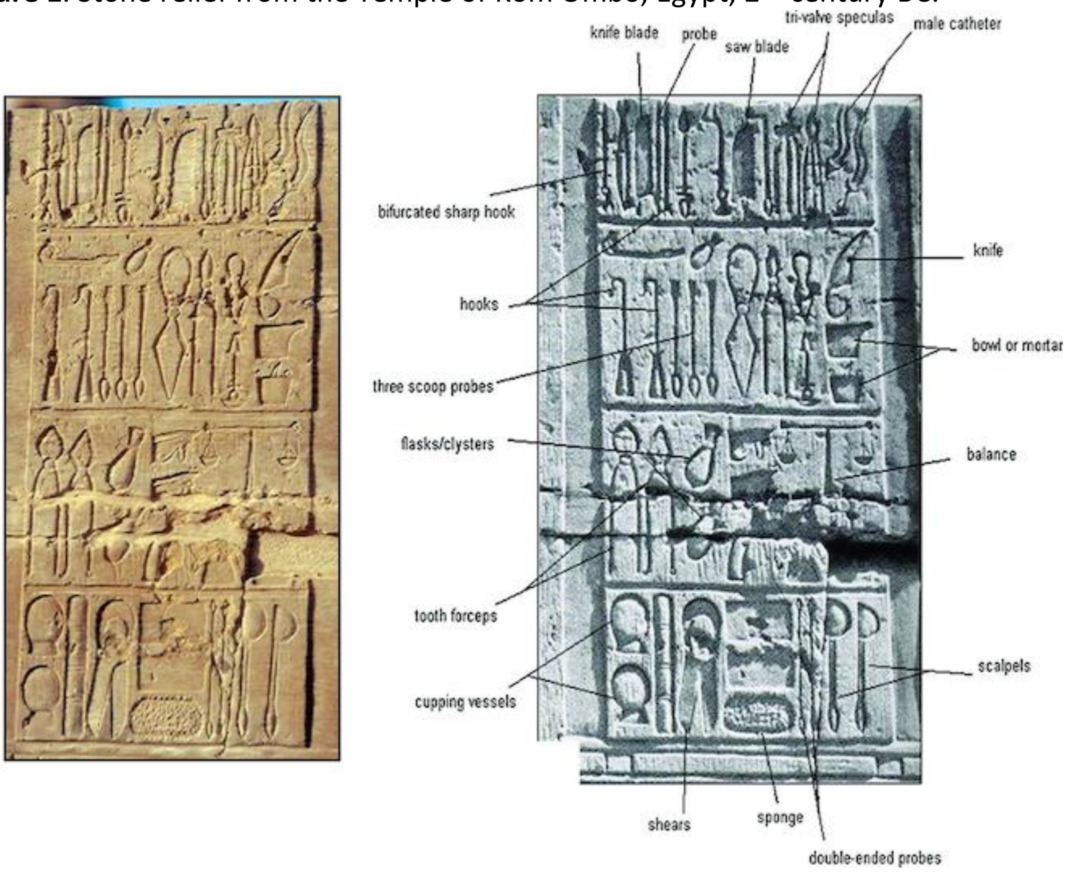
Dissatisfaction with these affairs motivated separation of elective and emergency general surgical patients (2-5). At its core, this new 'acute surgical unit' (ASU) model dedicated a general surgeon solely to EGS patients, with no elective commitments. Typically, these services were also supported by similarly dedicated doctors-in-training (registrars) and protected access to operating theatres. Studies repeatedly showed superior outcomes for patients, staff and budgets (6).

However, uptake of the ASU model has been slow, predominantly due to equipoise about these benefits and resource limitations. This thesis aims to improve care for EGS patients, through [1] addressing key gaps in the ASU literature, [2] providing guidance for both national policymakers and hospitals considering implementing an ASU, and [3] defining future areas of research. However, to best appreciate the current scenario, we must first understand how general surgery evolved to its present state.

A brief history of surgery

Medical care has two main branches; surgery and medicine, evident in the structure of hospitals and the titles of some university medical degrees. This divide has long existed, between the less invasive 'medical' methods, focusing on the administration of ingestible or absorbable remedies and the more invasive 'surgical' methods, entailing therapy via physical objects, typically in a traumatic way. The first known non-lethal surgical procedures occurred as early as 3,000 BC in Ancient Egypt (7). This 'proto-surgery' included both ritualistic circumcision and the drilling of holes in the skull (trephination), as well as surgeries directed a specific pathology, such as suturing wounds and cystotomy for bladder stones (Figure 1). Surgeons in Ancient Greek and Rome performed limited surgery including amputations, but were distinct from physicians, as evidenced by the Hippocratic oath "*I will not use the knife, even upon those suffering from stones, but I will leave this to those who are trained in this craft*" (8). However, pain and sepsis limited a surgeon's reach. Entering the abdomen was a folly '*almost uniformly fatal... The chest and joints were also out of reach*' (9). The chief remit of surgery was the therefore management of external conditions, and medicine dealt with the internal maladies. From this arose the term ‘internal medicine’, which persists to this day (9).

Figure 1. Stone relief from the Temple of Kom Ombo, Egypt, 2nd century BC.

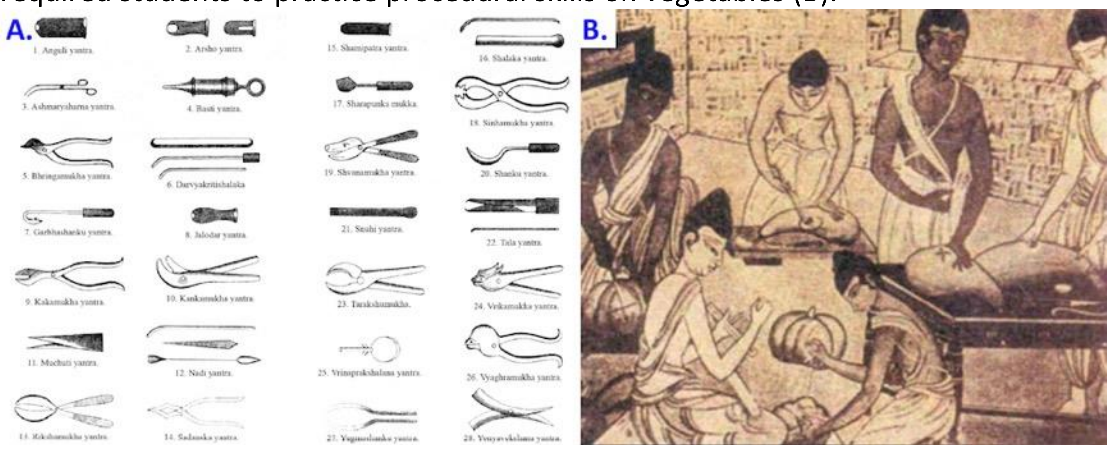


Modified from 2010 Saber *et al*. (10)

Surgery’s next stride forward would occur in India. Putting aside apocryphal feats such as transplanting the head of the elephant Lord Ganesha in Hindu mythology circa 2500 BC, the world’s first prominent surgeon was Acharya Suśruta (or Sushrata), who lived around 600 BC in Kashi (now Varanasi), in Northern India. In Sanskrit, Suśruta means ‘very famous’ or renowned, and his achievements were formidable. Unusually for his time, he supported cadaveric study; '*Anyone who wishes to acquire a thorough knowledge of anatomy must prepare a dead body and carefully observe and examine all its parts*' (11). His extensive treatise ‘*Suśruta Saṃhitā*’ described over 300 surgical procedures and 120 surgical instruments

(Figure 2.A). He was also experienced in trauma, suggesting six broad categories of accidental injuries, 12 varieties of fracture and 60 types of wound treatment (12). He described anaesthesia with wine or cannabis and gave realistic accounts of the steps and complications of caesarean section, tooth extraction and most famously reconstructive plastic surgery. In this time, state-sanctioned punishment included nose resection (13). Suśruta pioneered rhinoplasty with a rotated cutaneous forehead flap, which is still practiced today and referred to as 'the Indian flap' (12). Importantly, he instructed medical students, who were required to study for six years before commencing independent practice. This included surgical simulation on gourds, watermelons and cucumbers (Figure 2.B).

Figure 2. Suśruta devised elegant instruments similar to those in modern use (A) and required students to practice procedural skills on vegetables (B).



Modified from 2007 Whitaker *et al*. (14), and 2006 Saraf *et al*. (11).

Sashruta's early brilliance set an early high watermark standard for surgery, and incredibly his textbook remained reproduced and taught for >2000 years, earning him the moniker ‘father of surgery’ (12). Locally, this instructed practitioners of Ayurveda (traditional medicine native to India), forming the seminal texts (Vedas) for its two surgical streams, Shalya Tantra and Shalakya Tantra. Further afield, the Indian surgical advancements would in time spread to Europe; *'There is little doubt that* *plastic surgery in Europe which flourished in medieval Italy is a direct descendant of classical Indian surgery*' (15). However, after Sushrita, surgery in India stood still for millennia, until the reciprocal arrival of Western advancements in the 19th and 20th century.

The next point of progress occurred in China. Historically, Chinese medical teachings were philosophical rather than scientific. Key doctrines were the antithetical forces yin and yang, representing all opposing states (heat and cold, male and female etc.) and the five elements of nature (wood, water, fire, earth and metal). Imbalances in the human body of these forces or elements was thought to cause disease. A physician's armamentarium chiefly consisted of traditional Chinese medicines, of which there were a vast array. Leading practitioners '*daily tasted a hundred herbs*' (16). Belief in the powers of these herbal concoctions remains strong to this day. Other treatments included lifestyle advice, highly regarded physical therapies of massage and acupuncture, and surgery. Like all cultures, this was initially primitive; '*the truth is that ancient Chinese surgeons were limited to the simplest superficial operations. They treated with the scalpel boils, furuncles, ulcers of all sorts and small external tumours*' (17). They also practised punishment by castration (penis, testes and scrotum) from as early as 1100 BC. However, anatomical study did not exist, as abhorrence of shedding blood and reverence for the dead made cadaveric dissection impossible (16). Surgical excision was also spiritually unconscionable; '*It was incompatible with the Chinese religion to sacrifice any part of the body to cure disease. According to Confucius (551–479 BC), … whoever enters the realm of the dead mutilated cannot look forward to a reunion with his ancestors*' (17).

Surgery briefly had a champion in famed practitioner Hua Tuo (or T'o) (140-208 AD). He devised an effective anaesthetic mafeisan, thought marijuana- or opium-based. So aided, he was claimed to have performed laparotomy; '*When the person became unconscious, it was said he opened the abdomen, cleansed the bowels, cut away the diseased parts, stitched the wound, and applied a salve*' (16). After his death, surgeons were viewed progressively more dimly; '*Due to the religious stigma attached to the practice of surgery, the social position accorded to the surgeon became increasingly lower and thus made a revival of Chinese surgery impossible*' (18). Subsequently, Chinese surgery languished; '*Being the sole surgeon in the annals of ancient Chinese medicine, Hua had no known predecessor nor had he any successor. … After Hua Tuo, isolated surgical cases have been recorded in Chinese historical texts; however, these were merely flashes in the pan*' (17). From this brief period of brilliance in the third century AD until the arrival of Western doctors, Chinese surgery '*is conspicuous by its stagnation*' (16). This stasis led Austrian medical historian Max Neuberger to observe inn 1910, '*[Chinese surgery] presents the same picture today as thousands of years ago, a rare example of the petrifying effect of time'* (19).

We turn then to Europe. As we have seen, in all ancient civilisations, the profession of healing was merged with religion and superstition. In both early Eastern and Western civilisations, surgical procedures were originally performed by barbers, who held a more prominent role in society. In many cultures, the hair was thought inhabited by evil spirits, which could be expelled by cutting it off. In the first few centuries AD, the clergy practiced blood-letting with barbers enrolled as assistants. However, an edict in 1163 by the Council of Tours forbade monks and priests from blood-letting, and so barbers assumed sole responsibility for this panacea (20). The procedure was thought to cure almost any ailment; '*For therapeutic bleeding, use the veins nearest the diseased part; for preventive bleeding, use the large veins in the arms*' (21). Barbers' roles would expand to include tooth extraction, abscess drainage and amputations. Barbers would come to be readily identified by the bloodied rags hanging to dry on poles outside their stores. From this arose the modern striped barber pole.

In Europe from the fifth to fifteenth centuries, the Middle Ages (or medieval period) were an epoch of only modest progress medicine. Religion dominated all facets of life. Much of the population accredited disease to demons, sin or the will of God, the 'divine physician', who sent illness and healing according to His will. Medical teachings were based on inherited ancient pseudoscientific ideas surviving from Greek and Roman texts and scholasticism. This method of philosophical analysis emphasised using faith in reasoning, and sought to understand the world through debate, and inferences, rather than new empirical inspection and analysis. Until the 19th century, accepted teachings included imbalance of the theorised four principal fluids or 'humours' (black bile, yellow bile, phlegm and blood).

Britannia's subsequent surgical evolution serves as a useful example, with similar trends occurring simultaneously in other Western nations. In England, procedures for the next few hundred years were practiced by the aforementioned barbers and also a select group of non-doctor non-barbers, who for the first time self-described as 'surgeons'. Both groups learned their craft via an apprenticeship model, through first-hand experience. These two professional groups each created guilds, the

Company of Barbers and Fellowship of Surgeons respectively, which united in 1540 under King Henry VIII as the Company of Barber-Surgeons. Surgical practice continued to advance, and in 1745, these unions divorced, with the surgeons forming the Company of Surgeons. The manual work of surgery had led it to be viewed as a trade rather than an art, and unsuitable for respect or teaching in universities. This was in contrast to medicine, where university programs conferred degree upon students and the title 'doctor'. Such qualifications were mandatory for membership when the Royal College of Physicians was created in 1518 (22).

The disdain for surgery was epitomised by British parliament member Lord Thurlow's pronouncement in 1800, that there was '*no more science in surgery than in butchering'* (23). Surgery then was indeed agonising and often fatal. In the 1850s at the London Hospital, peri-operative mortality of lower limb amputations was 46% (24). However, the rehabilitation of surgery's pedestrian image had already begun. In 1800, royal charter created the Royal College of Surgeons of London and demanded prerequisites of a medical degree, to match the physicians. A second charter in 1843 gave the title used in present day, the Royal College of Surgeons of England. Similar travails occurred in other countries. For example, in France in 1756 the previously conjoined surgeons' and barbers' guilds separated, and in 1794, national law decreed equal status between surgeons and physicians (23). Unusually, in the antipodes the Royal Australasian College of Surgeons (1927) formed before that of the Physicians (1938) (25).

Once on equal status, the key enabler for surgery to flourish was the European Renaissance. This had provided a suitable environment to question classical medical doctrine and strive for new scientific study, 'seeing to believe' through first-hand observation. Like many areas of knowledge, this questioning approach dramatically improved anatomical understanding. The ancient Greeks were the first to produce accurate texts on animal human body structure through cadaveric dissection, reaching their apex in the works of Aelius Galenus (or simply Galen) (129-216 AD). Supported by the Christian Church and regarded as infallible, these were part of European medical curricula for >1000 years, until the Renaissance. In a collective effort most remembered for Belgian anatomist Andreas Vesalius (1514-1564 AD), Galen's works were circulated across Europe, with scholars encouraged to publish criticisms (26). At its height in the 17th and 18th century, thirst for dissection gave rise to grave digging for corpses ('body snatching') and homicide ('anatomy murder').

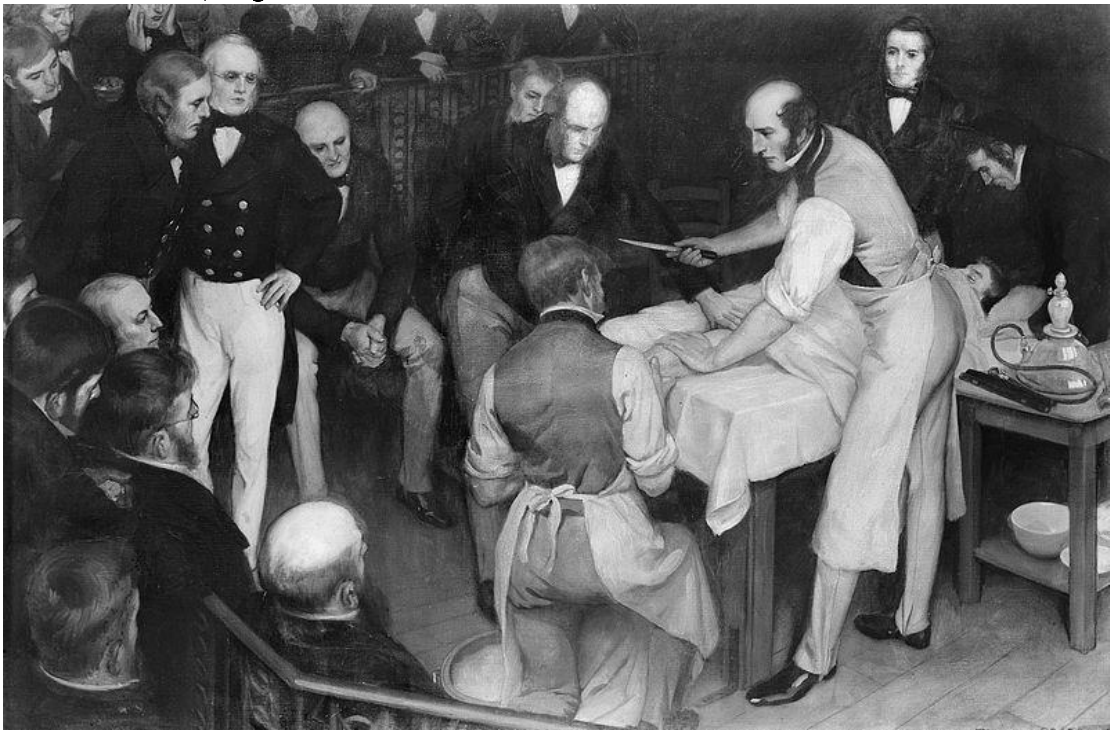
Against a background of widespread discovery, other fruits vital to the progression of surgery were teaching hospitals, anaesthesia and antiseptic techniques. Since ancient Greece and Rome and continuing into the European Middle Ages, hospitals were places of respite for the sick, old or poor and were run by religious institutions. From the 13th century, although still run by the church, hospitals began to geographically separate, then in 18th century Europe, hospitals embraced five dramatic changes. First was the uncoupling from religion. In the 18th century in London, secular funding allowed Westminster and Guy's hospitals to be built and St Bartholomew's hospital to continue operating. Second was the narrowing of focus. In Renaissance Europe, separate hospices formed for to permanently house the poor, aged or insane, and hospitals were now dedicated solely to the science of the sick. Third was specialisation. The development of niche physician expertise through separate wards for contagious, non-contagious and psychiatric disease had first occurred in 369 AD with the construction of the Basiliad (or Basilica) at Caesarea (now Cappadocia, Turkey) and continued with the magnificent >4000 bed Bimarstan al-Mansouri hospital in Cairo Egypt (constructed 1248 AD). In Europe in the 18th century, hospitals growing in staff and with remit now solely for medicine, specialisation could blossom. Fourth was the introduction of formal training for nurses, pioneered most prominently by Florence Nightingale (1820-1910). Fifth and finally, hospitals for centuries had been places of practice for physicians only. Surgeons plied their trade in small commercial establishments, self-identified by the aforementioned red and white barber's pole. For the first time, physicians and surgeons worked under the same roof.

Shortly thereafter, inhalation anaesthetics enabled surgery to evolve from Liston's 'speedy street performer' to Halsted's 'steady seamstress' (27, 28). Performed on fully sensate patients, procedures such as limb amputation for compound fracture prone to sepsis were known to be both '*lifesaving ... and at the same time horrific … the sounds of patients thrashing and screaming filled operating rooms*' (9) (Figure 3). Surgeons once operated as quickly as possible to minimise bleeding and the duration of excruciating pain. However, this mandated a limited spectrum of coarse procedures; '*the limits of patients' tolerance for pain forced surgeons to choose slashing speed over precision'* (9). Transformed through anaesthesia, surgeons could work methodically and delve deeper into the body. In 1846, Boston dentist William Morton first demonstrated ether, and in 1847 Scottish obstetrician James Young Simpson first used chloroform on humans. Patients began to survive their operations, and do so without writhing in torment; '*observers were struck by the stillness and silence*' (9) (Figure 4).

Figure 3. Left lower limb amputation performed in 1775 in St Thomas' Hospital, London, England without anaesthesia.

1775, oil painting, artist unknown. Work acquired in 1965 by the Royal College of Surgeons of England. In the front row sits Omai (1751-1779), a freeman 'noble savage' brought from Huahine, French Polynesia to England in 1774 by Captain Furneaux returning from Captain Cook's second voyage. The second Polynesian to visit Europe, this hospital visit '*formed part of the programme of entertainment provided for him'*, before his return to Huahine in 1777 (29).

Figure 4. Left lower limb amputation performed by Robert Liston (1794-1847) in 1846 in London, England under ether anaesthesia.



1912, oil painting by Ernest Board (1877-1934) commissioned by Henry Wellcome (30).

Subsequently, sterilisation dramatically reduced mortality. Since ancient Egypt and then ancient Greece, a wide range of herbal remedies had been in effective use, including honey, wine, vinegar and turpentine. The 19th century saw the isolated introduction of hand washing, antiseptic, rubber gloves and boiling or autoclaves for instruments. In 1847, when doctors habitually performed cadaveric examination immediately before assisting women in labour, Hungarian obstetrician Ignaz Semmelweis (1818-1865) found that hand washing with chlorinated lime water near-eliminated puerperal sepsis, the leading cause of maternal death (31). In 1867, English surgeon Joseph Lister (1827-1912) published a series of articles, reporting dramatic reductions in post-operative sepsis and death through carbolic acid used for hand washing, soaking dressings and sprayed over the operative field (32). However, these early key proponents were sadly derided in their lifetimes, and wide acceptance of sterility's benefits would not be achieved until early in the 20th century (33).

These advancements of anaesthesia, antisepsis and later antibiotics allowed surgical discovery to flourish. As the New England Journal of Medicine put it, *'Surgery had been, one might politely say, a modest contributor to medical progress. Between the mid-1800s and the 1920s, however, the coverage of surgical advances took up half the Journal'* (9). Surgeons began reporting new 'firsts' almost monthly, with the first non-fatal thyroidectomy, gastrectomy, appendicectomy, prostatectomy and brain tumour resection all occurring before 1900 (9). Further reductions in peri-operative mortality came through the development of intravenous fluid and electrolytes, antibiotics, blood banks and nasogastric intubation. For example, in EGS patients with perforated appendicitis in American tertiary centres, the 25-year period encasing World War II saw mortality drop from 19% to 3% (Table 1) (34). Key subsequent innovations included organ transplantation and minimally invasive surgery, reducing '*the debilitating, half-meter-long abdominal and chest incisions to a half centimetre*', and take the reader to the sophistication of the modern day (9). Surgery is normalised, the average American will undergo seven procedures in her lifetime, '*incisions [now] mere puncture wounds*' and as an American author noted in 2012, '*a teenage boy can undergo … repair of a severe coarctation of his thoracic aorta percutaneously on a Thursday and be well enough to sprain his ankle playing sports the following Saturday (as my son did not long ago)*' (9).

Table 1. Relationship between year and mortality from appendicitis with perforation amongst patients at John Hopkins Hospital, Baltimore, United States of America.

Series	Cases	Deaths	Percentage
1928-1931	85	16	19%
1931-1939	479	48	10%
1939-1947	325	23	7%
1947-1954	219	6	3%

Taken from 1955 Cantrell and Stafford (34).

What is general surgery?

As we have seen, initially surgery was its own specialty, with scope and prestige hard won from the barbers and physicians. By today's prism, all surgeons were then 'general surgeons', expected to be competent in both the emergency and elective management of all common surgical conditions. However, fascination with the disorders of particular organ systems led to many surgeons developing deep but narrow expertise and becoming 'specialists' (35). Progressively, the (general) surgeon began to relinquish much of his (or rarely, her) historical scope of practice

(25). As elsewhere, in the Australia in the 20th century, specialty units began to arise in Australian teaching hospitals. After the Royal Australasian College of Surgeons formed in 1927 with no internal subdivisions, in 1950 it officially recognised its first specialty in thoracic surgery. In 1976, General Surgery became a recognised specialty of the College. Presently there are nine specialties within the College (Cardiothoracic Surgery, General Surgery, Neurosurgery, Orthopaedic Surgery, Otolaryngology Head & Neck Surgery, Paediatric Surgery, Plastic & Reconstructive Surgery, Urology and Vascular Surgery). Separately, several other surgical disciplines have left the College to form their own institutions, namely Dentistry (1965), Ophthalmology (1969), Anaesthesia (1992) and Obstetrics and Gynaecology (1998).

With so many departures, what does a general surgeon do nowadays? The specialty's remit frustrates easy description. When in 1973 the American Board of Surgery attempted to define General Surgery, "*It was apparent that no definition existed... It had been ... informally defined by exclusion, and more exclusions had arisen almost yearly*" (36). Two decades later, Australian authors still grappled with a concise definition; '*general surgery is a discipline elusive of definition ... general surgery is the discipline treating those surgical conditions which are not clearly the preserve of specialist*' (37). The truth of this ongoing division is borne out by the specialties listed above who have separated from general surgery (but stayed within the Royal Australasian College of Surgeons) or from surgery overall (and left the College). It is also true within general surgery, where further subspecialisation is usual, with options of hepato-biliary, upper gastro-intestinal, lower gastro-intestinal (colorectal) and breast & endocrine.

Specialisation was deemed '*irresistible and irreversible*' by Professor Ian Gough, past president of the Royal Australasian College of Surgeons (4). Gradually, it has become clear that this inexorable trend carried several advantages. For patients, outcomes were often improved, where their procedures met the narrow remit of each craft group. Higher volume led to greater mastery, for both elective and emergency procedures, such as colon resection (38, 39). In addition, specialisation is also seen as offering greater remuneration, controlled hours and improved lifestyle (4). Specialisation also addresses other challenges faced by general surgeons and regulators. As knowledge and capability expands, it becomes impossible for a surgeon to remain familiar, let alone competent, with the increasingly complex surgical treatments available in multiple specialties. For example, peripheral vascular disease is now treated by open bypass, laser endarterectomy or transluminal angioplasty. Finally, medicolegal pressure has mandated that only specialists perform certain high-risk procedures, particular in the United States of America (USA) (37).

What are emergency general surgical conditions?

A simple definition is again elusive. An inductive argument would be that it the collection of presentations whose treatment may include a non-elective procedure from a general surgeon. The most common conditions include superficial and deep soft tissue infections, undifferentiated abdominal pain, appendicitis, biliary disease, pancreatitis, bowel obstruction, gastrointestinal inflammation (including diverticulitis) or bleeding, hollow viscus perforation, symptomatic hernia and trauma (40-44). The most common operations include appendicectomy, cholecystectomy, abscess incision and drainage/ wound debridement, hernia repair, colonic resection and exploratory laparoscopy or laparotomy (40, 41, 45).

Traditional care model

Brought to present day, the reader placing themself in the shoes of the head of a general surgical department has the substantial challenge in delivering care to both elective and emergency patients. Since time immemorial and remaining in use in much of the world today is the 'Traditional' (aka flexible) model, as described in this chapter's opening paragraph 'The Problem'. On-call is rotated between each general surgical unit. When on-call, surgeons and trainees remain allocated to elective operating lists and outpatient clinics and are additionally responsible for EGS referrals from either the emergency department (new presentations) or other inpatient units (referrals). These EGS patients are reviewed ad-hoc, where feasible around the structured elective responsibilities. EGS patients who are admitted typically stay with the same admitting team until discharge. The strengths of this approach are good continuity of care, workload shared reasonably fairly between teams and above all, provision of a service for EGS patients that is easily adaptable to varying degrees of specialisation and hospital size.

Drivers for change

The 'Traditional' arrangement is far from perfect. At the end of the 20th century, numerous other forces were simultaneously converging, amplifying the need to focus resources on EGS patients. These influences can be categorised as patient, staff and system factors (Table 2).

Table 2. Problems with the traditional model.

Patient factors	
Elective patients; frequent interruption or cancellation	(46)
EGS patients; frequent delays to review/ theatre	(3)
EGS population growing in number, age, comorbidities and cost	(47, 48)
EGS patients have unacceptably high mortality	(49, 50)
EGS patients with biliary disease are less likely to have surgery on 1st admission	(49, 51)
Staff factors	
After-hours operating common	(3, 46)
>80 hours work/ week common	(52, 53)
Specialisation: declining number of general surgeons relative to population	(54)
Specialisation: parallel call per specialty unfeasible	(35, 37)
Specialists may have reduced skills & desire to provide EGS on-call	(55, 56)
On call consultants periodically unavailable	(57)
Ill-defined handover of patients	(58)
Lower levels of trainee supervision; consultant input often limited	(50, 55)
Trauma surgeons face reduced operating volume and satisfaction	(59)
System factors	
Prioritisation of elective throughput, with EGS patients managed ad-hoc	(46)
EGS patients disseminated across wards often unsuited to the acutely unwell	(55)
Policies to reduce patient time in the ED may be poorly met	(60)
Policies to reduce unsafe staff hours may be poorly met	(61-63)
Relatively lower remuneration for EGS care	(64, 65)
Large variation in outcomes between institutions	(9)

ED: emergency department. EGS: emergency general surgery

Drivers for change: Patient factors

Most obviously, when staff within a Traditional structure have simultaneous elective and emergency commitments, some patients must always wait. Sufficient life- or limb-threatening presentations occur that interruptions to elective work remain common (46). Van Riet's systematic review found that compared to models providing dedicated emergency operating theatres such as the ASU, Traditional (aka flexible) policies increased elective patient day-of-surgery waiting time and cancellation rate (1). However, the majority of EGS patients can be temporarily deferred. Without protected daytime theatre access or staff, after-hours operating is standard (66). This timing fails to align with delivery of best care; '*Humans have a marked circadian preference for sleep at night and, even under optimal conditions,* *being awake at night is associated with impaired performance*' (67). This scheduling leads to preventable deaths. While results are somewhat mixed, the largest systematic reviews to date, enrolling 350,000 – 2,957,000 patients, suggest that evening or night-time operating is associated with increased patient mortality by adjusted odds ratio 1.16 – 1.26 (68, 69). The causes are likely multi-faceted, and may include increased fatigue-related human error, selection bias of more unwell patients, service delivery by more junior surgical and anaesthetic staff, reduced supervision and absence of the full suite of ancillary staff normally available in business hours.

The EGS population is becoming ever larger, older, more comorbid and more costly (47). Annually in the USA, these patients comprise >20% of both all hospital stays (>5 million EGS admissions) and all inpatient costs (US $341 billion) (48). Proportionately large numbers of EGS admissions occur annually in the United Kingdom (>619,000 admissions) (70) and Australia (>365,000 admissions requiring surgery) (71). Already massive, the number of EGS patients is increasing inexorably by >30% each decade in the USA and Europe (3, 72). This increase exceeds population growth. The reasons for this are unclear, and may include greater life expectancy and higher rates of comorbidity.

Preventable patient deaths demanded attention. In general surgery, although emergency patients represent only one quarter of all admissions (70, 71), they comprise over half of all deaths. This is true both in the United Kingdom (49) and the USA (73). For example, in 198 reporting private hospitals in the USA during 2005-2008, death occurred in 3,883 of 67,445 (5.7%) EGS patients compared to 3,243 of

406,174 (0.7%) elective general surgery patients (74). For almost any given major procedure, compared with elective patients, EGS patients suffer higher mortality rates (74), and allocating them resources saves lives (40, 41, 75, 76). In Britain, the unacceptably high mortality rates of EGS patients were highlighted repeatedly by the National Confidential Enquiry into Patient Outcome and Death, including in years 1990, 1996, 2001 and 2003. This body recommended the dramatic structural changes that would come to define innovation in emergency surgery, and perhaps the employment covenant required to continue to staff it; '*All hospitals which admit patients for emergency procedures should have an emergency surgery list, staffed and in a fully-equipped theatre suite… Anaesthetists and surgeons rostered for emergency work should be free from other commitments: this should be a fixed part of the consultant contract*' (50).

When treated within the Traditional structure, patients have a lower chance of receiving the surgery they need. This is particularly so for patients with biliary disease, such as biliary colic, acute cholecystitis and gallstone pancreatitis. This occurs as some centres, in an effort to combat the aforementioned high rates of after-hours operating, prefer where possible to stabilise emergency patients with biliary disease, discharge them and booked to a future elective list. However, 15-30% of these patients with untreated biliary pathology will re-attend the emergency department before their elective procedure has occurred (49, 51). These preventable additional visits represent ongoing suffering for the patient, interrupt their leisure and employment, and consume healthcare resources.

Drivers for change: Staff factors

With operating rooms traditionally allocated to elective lists and limited capacity for unplanned additions, after-hours operating has long been the norm for emergencies. Amongst comparative EGS studies published 2000-2020, 40% of appendicectomies within the Traditional structure were performed after-hours (Appendix 1). This lifestyle is clearly unappealing (77).

Long staff hours are required to run a Traditional model, with staff servicing elective patients in the day and emergency patients in the evening. In the USA in 2006, surgeons-in-training ('residents') averaged 95 hours/ week (53). In Australia in 2007, 97% of surgeons-in-training ('registrars') exceeded 85 hours/ week (52). Surgeons fared little better, typically working 80-85 hours/ week (52, 78). Accounting for days off, commuting and time awake at home, this implies many days with <6 hours sleep. This may impair patient and staff safety. Extended wakefulness of 17-19 hours has been shown to cause impaired cognition equivalent to a blood alcohol level of 0.05% (79). Over the long term, chronically poor sleep increases the risk of professional burn-out, as well as obesity, diabetes mellitus, cardiovascular disease and cancer (80).

Specialisation's rewards, as discussed earlier, were achieved at a cost. These included fewer general surgeons with broad ability, replaced by those with ill-defined limits to their comfort zone and reduced desire to support EGS services (55). In 2008, the president of the Royal Australasian College of Surgeons noted '*specialisation tends to be accompanied by erosion of competence in the broad scope of the major specialty*' (4). Fewer Australian surgical trainees and consultants wish to participate in on call; '*an emerging workforce issue has been observed where junior surgeons pursue career paths that are not associated with emergency surgical care, and senior surgeons increasingly opt out of emergency surgery on-call rosters or retire altogether*' (52). An example in point are Australian general surgical trainees aspiring towards subspecialisation in breast and endocrine surgery, amongst whom less than 40% would consider providing EGS on call (56). This trend has been rebuked by General Surgery Australia, whose 2010 '*12 Point Plan for Emergency General Surgery*' has as its first point '*Emergency general surgery is a continuing core competency of a general surgeon*' (66). In the United Kingdom, practitioners describe staff '*more committed to their specialties than to the generalities of the acute intake*' (35) and '*an increasing discrepancy between the numbers of emergency … admissions in the National Health Service and the numbers of surgeons willing or trained to treat them*' (81). Additionally, splitting surgery into an ever-more fractionated pie created difficulties in providing parallel on-call for each division (35). This was exacerbated by a lack of contractual obligation for EGS on call, with surgeons instead participating '*out of duty*' and '*goodwill*' (4, 64). Many viewed emergency surgery as a '*necessary inconvenience*', '*disruption*', '*burden*' or '*frustration*' (82), with surgeons more committed to their specialties than to the generalities of the acute intake (35). While a different specialty, the 2021 position statement of the American Academy of Otolaryngology–Head and Neck Surgery echoed the mood of many general surgeons within Traditional systems, describing on-call as an optional service '*graciously accepted*' in the past, but which due to poor remuneration and its ability to '*adversely affect the physician's quality of life*', may '*no longer be sustained*' (83). Thus, specialisation and evolving aversion to broad emergency responsibilities reduced the pool of surgeons participating in EGS on-call rosters.

In some nations, this has been exacerbated by the relative decline in the number of general surgeons relative to other surgical specialists and population growth. In the USA between 1970-2010, cumulatively the number of general surgeons grew 17%, far outstripped by growth of other surgical specialties by 102% and of the population by 39% (Table 3). In contrast, in Australia between 2005-2020, both general surgery and the other specialties administrated by the Royal Australasian College of Surgeons enlarged at a pace similar to each other, with both well ahead of population expansion (Table 4). However, as discussed above, the number of general surgeons may belie the true state of affairs, with many opting out of EGS on-call (52, 56, 81).

Another sequelae of specialisation is the creation of segregated staff 'silos' which may poorly integrate, resulting in fragmented care for patients. Trainees will typically move from one specialised unit to the next, sequentially receiving the narrow teaching and elective operating exposure of each. Given a trainee will never have rotated to all specialties, this may poorly prepare them when called upon to provide after-hours 'cross-cover' for all surgical emergencies. For example, general surgical trainees may receive little training in scrotal surgery, and a recent United Kingdom survey found only 35% felt competent to cross-cover urological patients (86).

Table 3. Percentage growth rates in the number of general surgeons, other surgical specialties and the United States of America population.

Years	General surgery	Other surgical subspecialties	United States population
1970-1980	11%	42%	11%
1980-1990	3%	28%	10%
1990-2000	3%	8%	7%
2000-2010	-1%	2%	6%
Compounded	17%	102%	39%

Taken from the 1992 Lord (37), and the American Medical Association Council on Long Range Planning and Development 1990 (54).

Table 4. Percentage growth rates in the number of general surgeons, other surgical specialties and the Australian population.

Year	General surgeons Number (% change from prior cell)	Other surgical specialists † Number (% change from prior cell)	Australian population Number (% change from prior cell)
2005	1,170 (n/a)	2,192 (n/a)	20,311,500 (n/a)
2010	1,381 (18%)	2,708 (24%)	22,172,500 (9%)
2015	1,621 (17%)	3,244 (20%)	23,984,600 (8%)
2020	1,892 (17%)	3,592 (11%)	25,683,400 (7%)
Compounded	62%	64%	26%

n/a: not applicable. †: excluding general surgeons, ophthalmologists and obstetrician/ gynaecologists. Taken from the Royal Australia College of Surgeons (84) and the Australian Bureau of Statistics (85).

The problems created by specialisation for broad on-call services were visible from the start. In 1951, only one year after Cardiothoracic Surgery became the first specialty of the Royal Australasian College of Surgeons, the University of Sydney Dean of Medicine Sir Dr Charles Bickerton Blackburn warned of '*an increasing tendency for specialties to become isolated medical cults rather than parts of a coordinated system*' (25). Surgical federations have felt able to mitigate the downsides, and the subsequent decades saw specialisation flourish. However, more than 40 years later near the turn of the millennium, Australian surgeons were still noting the challenges, observing '*some of the difficulties which might arise if ever most surgeons became super-specialists relate to staffing of emergency rosters*' (37).

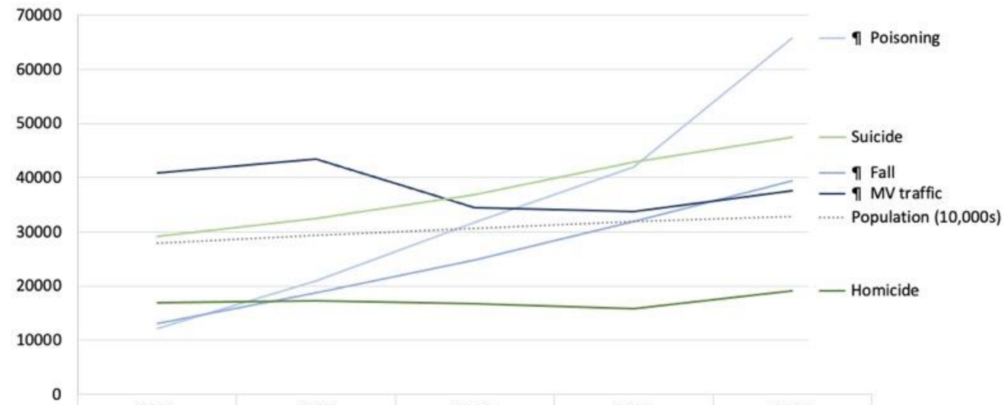
Supervision of doctors-in-training was also problematic. The concept of surgeon as 'consultant' over time led to diminished involvement in emergency patient assessment, decision making, and procedures (35). Patients still need to be seen by somebody, and increasingly '*"somebody" is usually a junior doctor*' (67). In the surgical department, as in other departments, a pyramidal staffing structure exists, with numerically more junior than senior medical staff, who by design supervise and so comprehensively assess few patients themselves. Hence, the majority of EGS patients, acutely unwell, complex and undifferentiated, are seen by junior staff, who then liaise up the hierarchy (55). Rostering to allow study for fellowship examination typically protects senior trainees, so once again patients are more likely to be seen by doctors not yet on, or early in, accredited training. Formalisation of consultant surgeon input varies, and typically includes daily telephone contact and brief weekly in person ward rounds. Hence, the EGS patient, substantially more unwell than their elective counterparts, may be managed for long periods, or their entire admission, without in person consultant involvement (35). This structure, with care provided to a high degree by junior doctors, continues into the operating room. In the United Kingdom, the 1996 National Confidential Enquiry into Patient Outcome and Death data reveals that for patients who died after undergoing a procedure, the surgical and anaesthetic staff member was an unsupervised 'senior house officer' (doctor not in accredited training schemes) in 20% and 47% of cases, respectively (50). These figures were alarming. A typical perspective is provided by Tincknell *et al*.; '*The NCEPOD drew our attention to the poor operative outcomes in emergency surgical patients undergoing operative intervention by junior surgical staff without consultant supervision during anti-social hours*' (87).

Changing patterns of trauma also created tensions for staff within the Traditional structure. As discussed below, trauma surgeons performed less trauma surgery, and transition to also deliver EGS care seemed an attractive proposition (88). Now and for the past 30 years, for persons aged 1-35 years, the leading cause of death is unintentional injury, predominantly from motor vehicle accident. This is true in both developed and (especially) developing nations (89-91). Somewhat paradoxically therefore, since the 1980s, trauma specialists have found their work increasingly untenable. Surgeon satisfaction and trainee applications plunged. The reasons for this was above all the increasingly non-operative nature of trauma management, followed by the predominance of night work, interference with elective schedules, 'high stakes and high stress', repeated exposure to grievously injured patients, 'negative patient factors' (such as treatment non-compliance, higher rates of substance abuse and lower rates of insurance), fear of contracting both human immunodeficiency virus and litigation, and poor reimbursement (78, 92, 93).

The severity of the key issue, the reduction in trauma operative load, was profound. In the USA in five years alone, between 1994-1999, the annual number of laparotomies per trauma resident decreased from 30 to 21 (92). The explanations for this are multifactorial, involving fewer trauma patients, less serious injuries and greater non-operative management. Relative to population growth, the reduction in injury number and gravity is well documented. Deaths by injury provide a useful correlate for rates of non-fatal trauma. Across the USA during 1999-2019, deaths due to motor vehicle accident declined relative to population (Figure 5). A typical urban trauma centre in this period observed no significant change in number of admissions for motor vehicle crash (its largest patient group) but a >30% reduction in mean patient injury severity scale score (88). Surgeons observed '*patients who sustain trauma in our catchment area are simply not as badly injured as they were in the mid-1980s' (88).* Explanations start with road safety legislation, including speed limits, safer cars (seat belts, airbags and crumple zones) and helmets for cyclists and motorbikes. Interpersonal violence also stagnated, secondary to an ageing population, improved economic conditions, violence prevention programs and changes to law-enforcement practices (88). While Figure 5 reveals the number of fatal suicides (representing <5% of all suicide attempts, and far exceeding the number of homicides) increased, the proportion involving firearms decreased, further reducing the number of survivors requiring operative intervention (89). Lastly, the increasing number of patients injured by falls, directly related to the ageing population, more commonly require an orthopaedic or neurosurgical procedure than a thoraco-abdominal one from a trauma surgeon.

When patients are injured in ways historically requiring a trauma procedure, they are now increasingly managed non-operatively. The key reasons are technological advances in radiology, and corresponding greater comfort in observation. The 1990s and 2000s saw cross-sectional imaging become ubiquitous, in the form of ultrasonography and especially computed tomography imaging (CT scan). After the first American CT scan in 1973, 62 million CT scans were performed in the USA in 2007 (94). Separate to the well-founded concerns regarding overuse and radiation harms, for injured patients this imaging often reduced the need for diagnostic peritoneal lavage or laparotomy. Simultaneously, breakthroughs in interventional radiology allowed embolisation of bleeding organs or vessels, and radiologically-guided percutaneous drainage of collections. Subsequently, non-operative management became common place for both blunt and penetrating trauma (59, 92). In this quandary, trauma surgeons looked for ways to increase operative load, salary and protected time off work. Moving towards an ASU model held appeal; '*The most practical solution is to increase the volume of emergency general surgery performed by trauma services ... one's role might evolve from trauma surgeon to "acute surgeon"* ' (88).

Figure 5. Selected causes of death by injury in the USA, 1999-2019.



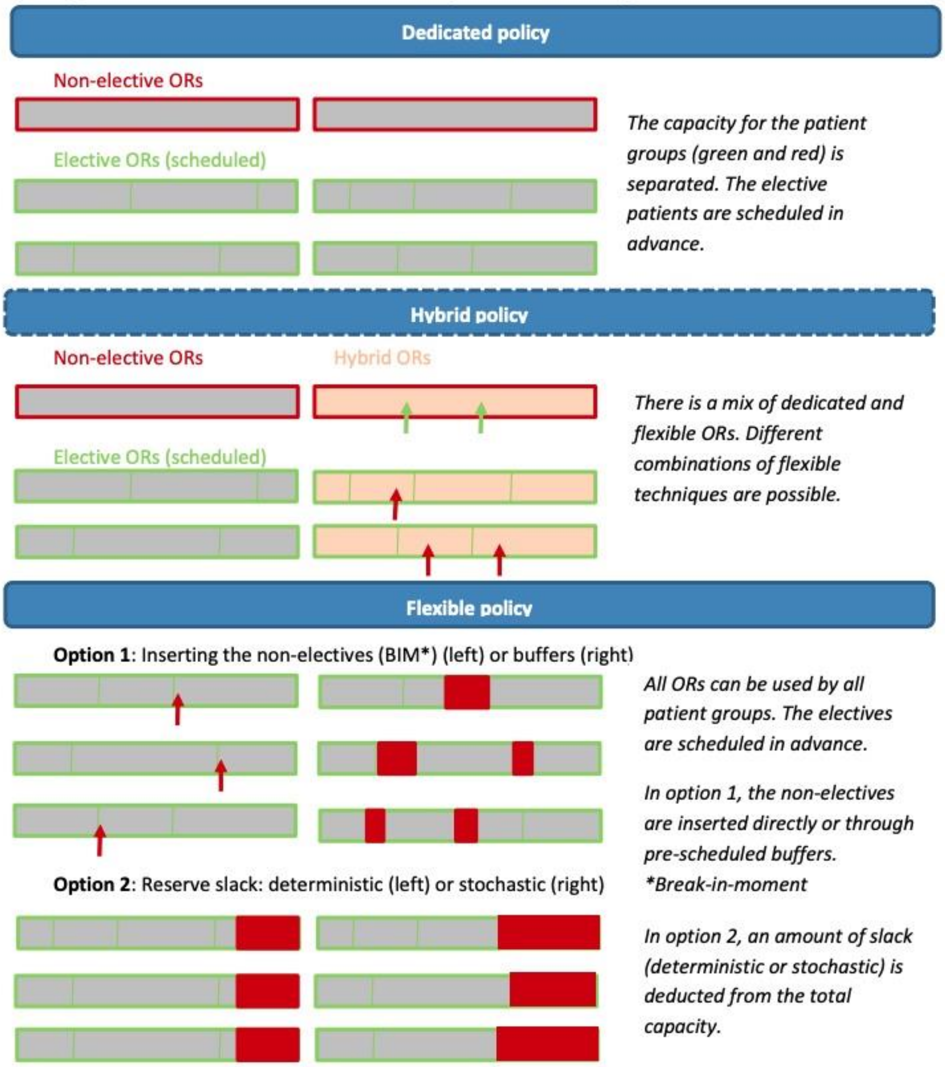
	1999	2004	2009	2014	2019
¶ Poisoning	12186	20950	31758	42032	65773
¶ Fall	13162	18807	24792	31959	39443
¶ MV traffic	40965	43432	34485	33736	37595
Suicide	29199	32439	36909	42826	47511
Homicide	16889	17357	16799	15872	19141
Population (10,000s) †	27904	29281	30677	31839	32833

¶: unintentional injuries. MV: motor vehicle. USA: United States of America.
Fatality and population data taken from the Centers for Disease Control and Prevention (89) and the World Bank Group (95), respectively.
Leading causes of unintentional death by poisoning include alcohol, opioids, sedatives, psychotropics, anti-epileptics and anti-inflammatories (96).

Drivers for change: System factors

Hospitals have traditionally prioritised their surgical resources for the needs of elective patients. Elective procedure waiting lists often attain political or at least institutional importance, with incentives and penalties to drive performance. The Royal Australasian College of Surgeons notes with concern, '*There has been a drive in healthcare towards the reduction of elective surgery waiting lists. This is seen as an attractive way to demonstrate success to the community'* (5). Hence, hospitals typically ‘*ring-fence*’ funding, operating theatres, peri-operative staff and administrators to meet these targets and to maximise utilisation of expensive theatre time (97). Administrators and politicians often lack awareness of EGS patients, or the need for after-hour services. In Australia, clinicians feel compelled to state the obvious ‘*Patients in hospital don't stop requiring ... care at night*’ (67). In the United Kingdom, surgeons state ‘*there is a widespread belief that most logistic problems relate to elective … cases which can usually be handled between 9am and 5pm … the extent of emergency surgical care that is required … is underappreciated*’ (81). Providing resources for non-elective patients have often been a secondary consideration. The Honourable Peter Garling’s commissioned inquiry into acute care services in New South Wales found that ‘*there is significant emphasis on the delivery of planned surgery and emergency surgery is essentially required to fit around it*’ (98). This poor trade-off means systems frequently did not meet mandated time-to-surgery guidelines for EGS patients (49). The Royal College of Surgeons of England notes this ingrained inequality; ‘*finite resources, such as consultant staff and theatre availability, are still systematically targeted at lower-risk patients having planned procedures, discriminating against sicker patients who need emergency abdominal surgical care*’ (99). Addressing this tension has attracted both economists (1, 100) and surgeons (101), with similar conclusions; allocate resources to both elective and emergency patients, in a manner adapted to the local setting (Figure 6).

Figure 6. Three operating theatre models for emergency general surgical patients.



From 2015 Van Riet *et al*. (1)

The physical location of patients in the Traditional structure may impair care. Depending on the day of the week, EGS patients may be admitted to the home ward of subspecialty units including upper gastro-intestinal, hepato-biliary, colorectal or breast and endocrine surgery. Nursing staff accustomed to their specialty unit's typical patient may be poorly equipped for acutely unwell EGS patients. Conversely, patients arriving through the day may be admitted to whichever beds become available. This scenario, of one team caring for new unwell patients dispersed across the hospital, is challenging. Clinicians describe '*the inefficiency of this process, with the admitting team spending almost as much time rushing from ward to ward as* *with their patients*' (35). Regarding EGS patients in a New Zealand hospital, Perry *et al*. report '*it was not uncommon for them to be scattered across as many as seven different wards, resulting in geographical dislocation … creating the so-called safari ward rounds as well as resulting in patients being cared for by nurses with no experience in patients with general surgical pathology*' (102).

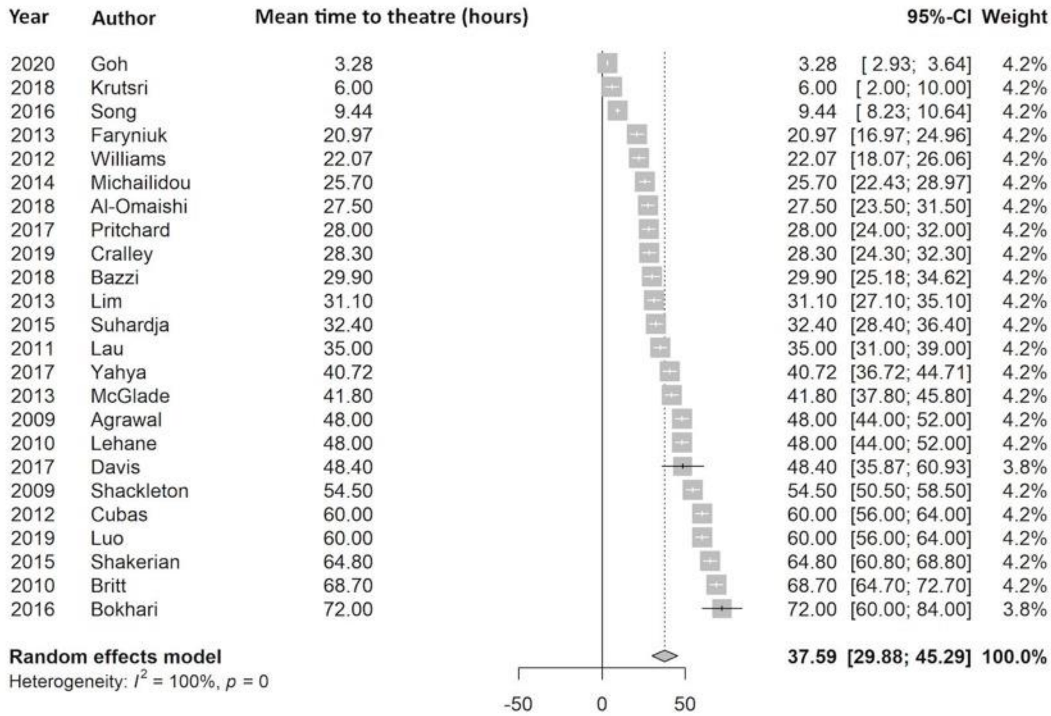
Existing models of care were challenged by new policies aimed at improving patient care and health system efficiency. In Australia in 2009, a four-hour national emergency access target was introduced. This stipulated that 85% of patients must spend less than four hours in the emergency department from arrival to admission, transfer or discharge. While national objective and subjective studies a decade later would show mixed results (103, 104), it was clear that surgical departments had to alter rostering to reliably deliver rapid emergency assessment.

Separately, across the globe, governing bodies introduced safe work hour schemes. In Britain, the 1991 New Deal nominated (although routinely failed to achieve) junior doctor roster limits per week of 83 hours (1993) then 72 hours (1994) then finally 56 hours per week (2001), and a banding system of salary multiplying to pay doctors for after-hours work (105, 106). In 1993, the first edition of the European Working Time Directive mandated a range of measures, including 11 hours continuous rest in every 24-hour period, and 48 hours continuous rest per fortnight. While doctors in training were initially specifically exempt from these protections, subsequent revisions removed this exemption and limited rosters averaged over 6 months to a mean of ≤58 hours (2004 amendment), ≤56 hours (2007 amendment) and ≤48 hours work per week (2009 amendment) (107-109). After this, these limits were largely achieved, aided by the above financial incentives, as well as court rulings in Spain and Germany enshrining the principle that time on-call was work, even if asleep (109). In 2003 in the USA, the Accreditation Council on Graduate Medical Education's Work Hours Duty policy set an 80-hour per week limit (averaged over four weeks), no more than 24-hours on-call, and, averaged over four weeks, one day off work per week and on-call ratio no more frequent than one-in-three (53). This policy remains unchanged to present day (110). Locally, in 1999 the Australian Medical Association first delivered its guidance '*Hours of Work, Shiftwork and Rostering for Hospital Doctors*' (111). Then and unchanged in updated editions (61), definitions of hazardous work included <10 hours continuous rest in every 24-hour period, and >70 hours work per week. In 2007, the Royal Australasian College of Surgeons' inaugural relevant position statement '*Standards for Safe Working Hours And Conditions for Fellows, Surgical Trainees and International Medical Graduates*' supported these standards and recommended surgeon and registrar on-call ratios be no more frequent than one-in-four (112). In 2013 the College has resisted further reductions, stating '*the ideal working week for surgical trainees is 65 hours to maintain training and safe patient quality care*' (113), and in 2018 re-affirmed limits of <70 hours work per week (114). These edicts by the Australian Medical Association and Royal Australasian College of Surgeons remain non-binding, and recent standard and grey literature contains examples of ongoing unsafe hours (115, 116). However, taken together, meeting these global directives provided further impetus to move away from the Traditional structure of after-hours operating and from long periods of on-call, and towards daytime EGS lists and shift work (87, 117, 118).

The difference in salary is also a decisive motivator, well-known but poorly reported for fear of appearing greedy. A surgeon's income '*is almost directly proportional to the number of procedures he or she completes*' (22). Elective patients are efficiently triaged and assessed prior in outpatient clinics, which allows for a similarly efficient number of elective procedures to be performed per theatre session. In contrast, EGS patients arrive both unwell and undifferentiated. Significant time is required per patient for resuscitation, assessment and investigation, and a large proportion will be successfully managed without a surgical procedure, for example requiring instead antibiotics, a nasogastric tube or a radiological intervention. Compared with time spent operating, funding models pay surgeons less well for delivering non-procedural care. Consequently, remuneration for staff providing EGS care is routinely less than that for elective work, despite the overtime multiplier of anti-social hours. Therefore, any self-interest within a surgeon will align far more naturally with elective than EGS work. A standard perspective has been '*the public hospital system does not appear to have a high regard for emergency surgery if ... remuneration for surgeons for after-hours work are taken as indicators*' (64).

Lastly, the ad hoc nature of the Traditional model created a spectrum of care. Individual general surgical departments may be relatively over- or under-staffed or have other human or institutional barriers to safe prompt treatment. Subsequently, wide variation existed in mortality and timeliness outcomes between sites. For example, from emergency department arrival to skin incision, patients undergoing emergency cholecystectomy within the Traditional system could wait anywhere between 5 and 70 hours depending on their hospital (Figure 7). Such disparity in healthcare quality became increasingly untenable and demanded increased resources for EGS patients to reliably deliver acceptable outcomes.

Figure 7. Variation in time to theatre for patients undergoing non-elective cholecystectomy within traditionally structured units.



Studies (43, 51, 118-139). Data presented as means within 95% confidence intervals. Forest plot prepared by Dr Michael O'Callaghan, Flinders Medical Centre/ University of Adelaide.

Lessons from the acute medical unit

These patient, staff and system factors fuelled growing discontent with the Traditional structure of care for emergency surgical patients in the 1990s. Departmental heads and policymakers looked for an alternative. Fortunately, within medicine, an instructive sea change had just occurred for emergency patients. Here too previously existed a system with non-elective patients admitted ad-hoc to specialty units and cared far on wards with variable preparedness to manage acutely unwell patients. In 1993, two hospitals in the United Kingdom chose to create a separate team for non-elective admissions, with its own ward. Two 'acute medical units' were created, in Leeds, England and Stobhill, Scotland (140, 141). Motivated by their positive results, in 1998 the Royal College of Physicians of Edinburgh and the Royal College of Physicians and Surgeons of Glasgow jointly declared the previous model as 'unfit for purpose' (142). This pioneered a worldwide shift. By 2011, 70% of Australian centres and >90% of hospitals in the United Kingdom would use the acute medical unit model (143, 144).

As we will soon learn was also later the case for acute surgical unit models, the acute *medical* unit would develop many synonyms, include the acute assessment unit, acute medical assessment unit, medical assessment unit, rapid assessment medical unit and others (143). Their core features were a designated hospital ward to receive unplanned medical inpatients, supervised by general medicine physicians with an interest in acute medicine, where assessment and treatment could occur for a defined period (typically 24-96 hours) before discharge or transfer to a less acute medical ward. These units also featured allied health teams including physiotherapists and occupational therapists and were often geographically collocated close to the emergency department, radiology and pathology services.

Within surgery, why general surgery first?

All surgical specialties must manage unplanned admissions, and balance scheduling of elective versus emergency procedures. However, general surgery as a specialty cares for by far the highest number of critically unwell patients requiring non-elective surgery. As discussed, this has traditionally occurred after-hours, often with poor outcomes. In the United Kingdom, the 2003 National Confidential Enquiry into Patient Outcome and Death lists non-elective procedures occurring after-hours (and ending in death within 30 days) for the specialties of cardiothoracic surgery, general surgery, gynaecology, maxillofacial, neurosurgery, ophthalmology, orthopaedic surgery, otorhinolaryngology, paediatric surgery, plastic surgery, urology and vascular surgery (145). Over 42% (122 of 285 patients) of these after-hours emergency cases were general surgical. More broadly considering patients regardless of mortality outcome, in 2004 a Scottish tertiary referral hospital found that general surgery comprised 48% (82,482 of 169,358 patients) of all emergency surgical admissions (81). In the USA, general surgery represents the massive majority of non-elective procedures. Over 700 of the nation's 6,090 hospitals participate in the American College of Surgeons' National Surgical Quality Improvement Program (146, 147). Recent publication of 2007-2017 data (which excluded plastic surgery and otorhinolaryngology, due to few cases) revealed that general surgery accounted for >70% of emergency procedures overall (132,030 of 173,890 patients) and those ending in death within 30 days (12,242 of 16,903 patients) (148). This scenario gave general surgery two clear imperatives to change away from the Traditional model. Firstly, the specialty cared for more patients undergoing higher-risk after-hours procedures than any other. For emergency patients, quality improvement initiatives stood to save more lives and provide the greatest good in general surgery. Secondly, general surgical elective activities were particularly prone to interruption. The greatest elective surgery efficiency gains were placed to occur in general surgery.

General surgery is uniquely well placed to pioneer new structures. Perhaps predictably, there are also more general surgeons than any other type. In Australia for example, the proportion of general surgeons to all surgeons has remained stable for the past 15 years at approximately one third (Table 4). At the individual hospital level, this means general surgery will have the largest staff pool, best suited to division into elective and emergency teams.

The first acute surgical unit

As set out in this chapter's opening paragraph 'The problem', an ASU's key features are a surgeon dedicated solely to emergency patients, and typically also a similarly allocated registrar and protected theatre access. The first ASU may have been established in 1980 in the USA at a site unspecified, according to a 2017 survey of American EGS centres (149). However, the first document such unit was established in Scotland, where EGS admission had risen 40% in 13 years (3). Addison *et al*.'s publication title states their intent clearly; '*Separating elective and emergency surgical care*'. In this new arrangement starting 1996, each week one surgeon and eight doctors-in-training (six present at any one time) solely engaged with the care of EGS patients. Over a 5 year period, despite a further 40% increase in the number of EGS procedures per year, the proportion performed after-hours decreased from 16% to 8% (3).

The model spread rapidly, with benefits repeatedly validated for a wide range of stakeholders. For patients, ASU implementation was associated with reductions in complications, mortality and length of stay, as well as time to review, time to theatre and for patients with biliary disease, rates of cholecystectomy on index admission (40-44, 51, 76, 102, 120, 125, 127, 133, 134, 139, 150-160). For staff, ASU establishment was associated with reduced total hours and rates of after-hours operating, and increased satisfaction and trainee supervision (3, 41, 133, 153, 155, 157, 161-167). Health systems reported either budget neutrality or cost savings (41, 154, 161).

Centres employed a variety of equivalent names of their acute surgical units, including the acute care and emergency surgery service, acute care surgery, attending of the week, emergency general surgery/ surgical unit/ service, surgeon of the week, surgical clinical decisions unit and surgical hospitalist. This melange of names was accompanied by a spectrum of structures. While the best described acute surgical unit contains a protected surgeon, registrar and theatre time, local scenarios and resource limitations have led some 'Hybrid' models to introduce only select aspects, such as surgeons allocated to EGS for half days, or no EGS-dedicated surgeon but still EGS-dedicated trainees and/or theatre access. Theatre modelling for the ASU (aka dedicated), Hybrid and Traditional (aka flexible) approaches can be seen in Figure 6.

Governmental support

Bolstered by the success of a handful of pilot programs, national bodies began recommending the ASU as the preferred model for general surgical departments to allocate resources for EGS patients. In United Kingdom in 2007, the Royal College of Surgeons of England released a position statement, emphatically titled '*Separating emergency and elective surgical care*' (168). The College's support of the model strengthened in 2013, when jointly with the Association of Surgeons of Great Britain and Ireland it published a subsequent position statement '*Emergency General Surgery'* (169).

In Australia, a raft of actions in New South Wales and Victoria led the way for national change. In 2008, the Honourable Peter Garling's commissioned inquiry '*Acute Care Services in New South Wales public hospitals*' found a raft of problems, and advised state-wide uptake of the ASU model wherever possible (46). On this topic, his leading two recommendations were:

a) *'The separation by facility, or operating list or otherwise, of planned or elective surgery from emergency or urgent unplanned surgery;*
b) *The introduction of an Acute Surgery Unit, which is a consultant led unit, the purpose of which is to undertake all acute surgery at the hospital within the 12 hour day time period'* (46).

In 2009, New South Wales Health duly released their first '*Emergency Surgery Guidelines*', supporting the ASU as its preferred structure (82). In 2010, the Victorian Government funded '*Good practice in management of emergency surgery: a literature review'*. Aimed at collating global options without recommending any, this flagged the ASU model as one of four possible strategies for balancing elective and emergency surgery, the others being dedicated daytime EGS theatre lists, leaving 'buffer' space in daytime elective lists (Figure 6) and planned after-hours EGS theatre lists (52).

The stance of the national bodies evolved accordingly. In 2008, the Royal Australasian College of Surgeons' '*Position statement on emergency surgery*' recommended '*dedicated emergency theatre space*' and rostering to make surgeons '*available to perform emergency surgery in a timely fashion*' (5). In 2009 the College convened the inaugural Emergency Surgery Workshop and released a consensus statement now supporting the separation of elective and emergency surgery (64), then in 2011 its policy paper '*The case for the separation of elective and emergency surgery*' for the first time specifically championed the ASU model (2). In parallel, General Surgeons Australia released their '12 Point Plan for emergency general surgery' (66). This systematically set out standard-of-care criteria now synonymous with the ASU model; consultant-led patient care (point 2) through dedicated EGS staff (point 3) separate to elective staff (point 4), with protected EGS theatre access (point 5) to reduce after-hours EGS operating (point 6).

In contrast, in the USA the American College of Surgeons has so far refrained from defining the ideal model, with their most recent '*Statement on Emergency Surgical Care*' calling for adequate staffing and funding, whichever EGS structure is used; '*optimal care can be delivered only if health care organizations commit the necessary resources and support, and appropriate reimbursement is provided by insurers*' (170). Change therefore occurred not due to national guidance, but rather through modification of the scope of trauma surgeons, and creation of a new sub-specialty; acute care surgery. In 2003, a joint meeting the of American College of Surgeons, American Association for the Surgery of Trauma (AAST) and other North American trauma associations created an ad-hoc committee to reorganise trauma and emergency surgery, formalised in 2005 as the Acute Care Surgery Committee. 2007 saw the development of a curriculum, assessment tools and site visits, with the first AAST-accredited Acute Care Surgery fellowship intake occurring at the University of Nevada in Las Vegas (171). Currently there are 28 such programs in the USA, with additional sites in the process of gaining accreditation (172).

The acute surgical unit model goes global

Support by these leading institutions gave the ASU model legitimacy. Numerous publications demonstrating favourable results created a stream of testimonials. Subsequently, establishment of acute surgical models has occurred in sixteen nations spread across all six inhabited continents (Table 5) (101, 173).

Table 5. Published acute surgical units, by continent and nation.

Continent	Nation	References
Africa	Rwanda	(44)
	South Africa	(174)
North America	Canada	(123, 130, 161, 165, 175-178)
	USA	(119, 122, 124, 132, 135-137, 151, 154, 179-187)
Asia	Singapore	(41, 139, 188)
	South Korea	(131)
	Taiwan	(189)
	Thailand	(43)
Oceania	Australia	(40, 51, 120, 121, 125, 126, 128, 133, 134, 138, 153, 155, 157, 160, 162, 163, 166, 190-201)
	New Zealand	(102, 159, 202-204)
Europe	Ireland	(205)
	Sweden	(206)
	The Netherlands	(158)
	UK	(3, 75, 117, 127, 150, 207-209)
South America	Brazil	(210)
	Ecuador	(76)

UK: United Kingdom. USA: United States of America

Doctorate objective

However, there remains much still to be done. Globally, many (perhaps the majority) of hospitals persist with the Traditional model. Clinical equipoise persists in the minds of many surgeons despite positive reports from the dozens of hospitals tabled above, and support by surgical bodies in the United Kingdom, USA and Australia. Those three countries alone manage >6,000,000 EGS admissions annually (48, 70, 71). This represents many patients, staff and health budgets which could experience superior outcomes. Hospitals considering implementing an ASU need evidence, as do national surgical bodies considering strengthening their policies in support of the ASU model.

It is the objective of this doctorate to fill these gaps in the literature, by answering the following questions:

- Locally, very little data exists on the ASU model in South Australia. At time of higher degree commencement (01/05/18), the sole publication was the author's scoping study on the Lyell McEwin Health Service's ASU (163). Also, there is a dearth of studies regarding factors affecting patient-reported outcomes in EGS, including none from the Southern Hemisphere. Does the ASU model work in this state, and what is the patient perspective?
- Nationally, at time of commencement, only seventeen of the approximately 210 Australian general surgery departments have published their use of the ASU model, or persistence with traditional or subspecialty models (Appendix 3). For the great majority of public hospitals in Australia, the model in use remains unknown. The untested assumption is that the silent majority have also considered or implemented an ASU. However, no attempt has been made to quantify uptake nor investigate lessons learned. What is the actual proportion of Australian public hospitals using the ASU model, and does the model affect the satisfaction and working hours of trainee and consultant surgeons?
- Globally, at time of proposal, three systematic reviews had been published, most recently in 2016 (58, 211, 212). These each identified between eight to seventeen studies comparing cohorts of patients managed within either the Tradition or ASU model, each comprising 6,112 – 6,921 total pooled patients.

However, these reviews often had narrow foci, for example enrolling only Australasian studies, or only those pertaining to patients with appendicitis or cholecystitis. The literature on ASU has since greatly expanded. A broad and updated review was expected to identify >50 studies, representing >100,000 unique patients, and with the highest available level of evidence be able to answer the question; does the ASU model work? Furthermore, can the model be applied to surgical specialties outside of general surgery, such as urology?

Chapter 2: Publication 1

Acute surgical unit improves outcomes in appendicectomy.

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Name of Principal Author (Candidate)	Ned Kinnear		
Contribution to the Paper	Submitted ethics application, collected data, performed data analysis, wrote manuscript first draft and acted as corresponding author.		
Overall percentage (%)	50%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/12/21

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper	Guided study design and refined the final manuscript.		
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Contribution to the Paper			
Signature		Date	

ABSTRACT

Background: Few large Australian studies have explored the impact of the acute surgical unit (ASU) model in appendicitis.

Methods: An ASU model commenced practice at our institution on 01/08/2012. In this retrospective cohort study, patients undergoing appendicectomy 2.5 years before (Traditional group) or after (ASU group) this date were compared. Primary outcomes were median length of stay, median time from emergency department (ED) referral to theatre start and proportion of cases performed in-hours. Secondary outcomes were rates of complications, open appendicectomy, consultant scrubbed for procedure, intensive care unit (ICU) admission and representation to ED with 30 days.

Results: After removing those with incomplete data, 1214 patients were enrolled; 465 in the Traditional group and 749 in the ASU group. There were no significant baseline differences between groups. Compared with the Traditional group, ASU patients had similar length of stay (1.81 vs. 1.81 days; p =0.54) and time to theatre (0.59 vs. 0.56 days; p=0.14), but a greater proportion of in-hours operation (72% vs. 79%; p=0.014). The ASU group also experienced fewer complications (9% vs. 6%; p=0.016), fewer primary open (4% vs. 1%; p<0.0001) or conversion-to-open appendicectomies (6% vs. 2%; p<0.0005) and had superior rates of consultant scrubbed in theatre (21% vs 56%; p<0.00001). Rates of ICU admission (1% vs. 1%; p=0.72) and re-presentation were unchanged (5% vs. 5%; p=0.46).

Conclusion: In our institution, the introduction of an ASU model was associated with more in-hours operations and safer care for patients undergoing appendicectomy.

Keywords: acute surgical unit, acute care surgery, emergency general surgery, appendicitis, appendicectomy.

1. INTRODUCTION

Appendicitis is one of the most common emergency general surgical presentations, with Australian incidence of 140 cases per 100,000 person-years (213). Despite interest in the non-operative management of some patients (214), laparoscopic appendicectomy remains the current accepted management in most cases (40, 41). Globally, appendicectomy is consistently the first or second most common emergency general surgical procedure (41, 45, 155, 163, 215). As such, appendicitis represents an acceptable yardstick of performance in the emergency general surgical setting. Such comparison is important to improve patient care, as outcomes remain surprisingly varied between institutions (216). The peri-operative mortality of appendicectomy has fallen dramatically likely due to advances in imaging, antibiotics and laparoscopic experience, but may still approximate 0.1 - 0.3% (217, 218).

Traditional systems for managing emergency general surgical referrals (including acute appendicitis) usually involves rotating call between different general surgical units. Registrars assess patients in between elective outpatient and operative responsibilities without dedicated acute on-call time. Consultant supervision tended to be variable, and theatre access was often only possible after hours or in-hours through deferral of elective patients (163). A cluster of factors including the decline in trauma surgery incidence, ongoing expansion of sub-specialisation, job dissatisfaction, staffing expense and potential increased morbidity risk of after-hours operating led to the proposal in 2001 of the Acute Surgical Unit (ASU) model (219). The key tenets of this structure were a dedicated on-site surgical registrar, an on-call general surgeon and an operating theatre, all without elective duties and dedicated to emergency referrals.

The first formal ASU in Australasia was introduced in 2005 (190). Many other centres followed suit, with generally positive results (58, 163, 212). However, only eleven sites have reported outcomes in appendicitis (41, 128, 155, 189, 191-196, 198, 200), only one study comprised >1,000 patients and none were from South Australia (200). Management of emergency general surgical presentations at our metropolitan tertiary referral hospital changed from the Traditional to the ASU model on 01 August 2012. This study aims to compare the outcomes of patients undergoing appendicectomy within either the Traditional or ASU model of care at our institution.

2. METHODS

A retrospective cohort study was performed, enrolling all patients undergoing appendicectomy at our institution during the Traditional (01/02/10 – 31/07/12) and ASU periods (01/08/12 - 31/01/15). Eligible patients were aged ≥ 18 years, underwent appendicectomy (Medicare Benefits Schedule code 30571 or 30572) and had complete data available. Data were collected from electronic hospital records. Manual reading occurred of all appendicectomy operation notes and discharge summaries from the principal admission plus any admission in the following 365 days. Primary outcomes were median length of stay, median time from emergency department (ED) referral for surgical assessment to theatre start, and proportion of cases performed in-hours (0800 – 1800). Secondary outcomes were rates of complications (220), negative appendicectomy, primary open appendicectomy, laparoscopic-converted-to-open appendicectomy, intensive care unit (ICU) admission and representation to the ED with 30 days. Complication data was obtained from discharge summaries from the principal admission plus any admission in the following 30 days. In our institution, time of referral to general surgery is electronically logged on ED software (HAS Solutions Pty Ltd, Pymble NSW Australia). Similarly, theatre start time was based on time of patient gurney arrival in an operating theatre, which is electronically logged on theatre suite software ORMIS (GE Healthcare, Parramatta NSW Australia). Rates of consultant scrubbed for procedure were obtained by cross-referencing ORMIS records of all scrubbed staff with departmental consultant rosters for each month over the five year period. Eligible staff were permanent employees who had obtained their fellowship qualification in any of general surgery, urology or obstetrics/ gynaecology.

Unit structure

We have previously described our ASU structure, handover routine and overall results (163). In brief, prior to introduction of the ASU, emergency general surgery on call rotated between a pool of sub-specialty general surgeons (colorectal, upper gastro-intestinal or breast/ endocrine). In this Traditional period, surgeons were on-site during business hours but had scheduled elective commitments. After-hours they were off-site but available, and surgeons reviewed all admissions on the following morning's ward round. Referred patients were reviewed by the sub-specialty unit's accredited general surgical registrar in between elective clinic or operating duties, or by their resident medical officer.

The new ASU employed four non-accredited general surgical registrars, with one on-site 24 hours/ day, 365 days/ year. The ASU registrar had no elective commitments. They were supervised by and shared workload with the accredited general surgery registrar of the on-call consultant's unit. Additionally, they were supported by the new role of an ASU consultant, who was on-site in business hours, again unencumbered by elective duties. A separate on-call consultant was on-site during business hours but with elective responsibilities, and then off-site on-call after hours. Handover occurs at 0800 and 2000 hours every day between the ASU registrar, sub-specialty registrar and on-call consultant. The latter two reviewed all new admissions on the morning ward round.

Operating theatre availability also changed. Traditionally, all emergency operating competed for access to a single emergency theatre. In establishing the ASU, arrangements were made for a second theatre to be staffed and available to the ASU on weekdays during 09.30–16.30 hours, and weekends during 09.30–12.00 hours. The hospital pool of anaesthetic staff provided for an anaesthetic registrar on-site 24 hours per day, with a supervising anaesthetic consultant on-site during business hours and off-site but available at other times.

To assess electronic database validity, 1% of individual patient records were manually obtained and compared with automatically generated information for every data point. All patient records were manually interrogated to obtain complication data. This study was performed in accordance with the Declaration of Helsinki, and ethics approval was granted by the Central Adelaide Local Health Network Human Research Ethics Committee (reference Q20151120).

Statistical analysis

Continuous data were summarized as medians with interquartile range (IQR), and significance assessed using the Wilcoxon (Mann–Whitney) test. This statistical test was chosen after confirming the non-parametric positively skewed distribution of the three data with continuous scale; age, length of stay and time to theatre. Categorical measures were summarized as proportions and assessed with Pearson's chi-square test. All tests were two-tailed, and significance was assessed at the 5% alpha level.

3. RESULTS

Demographics

Appendicectomies were performed on 1,572 adult patients in the enrolment period, 644 and 928 in the Traditional and ASU periods respectively. Of these, 1,214 patients met eligibility criteria, with 465 and 749 in the Traditional and ASU periods respectively (Table 1 and Figure 1). The groups were not significantly different in gender, median age or proportion with American Society of Anaesthesiologists physical status score 1. Further comorbidity and body mass index data was not available.

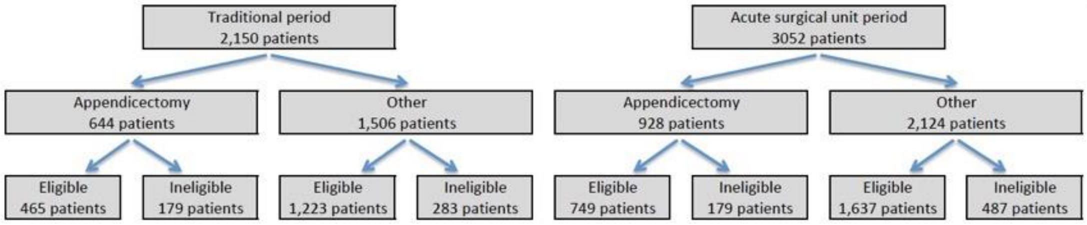
Primary outcomes

The groups were similar in median length of stay and median time from ED referral to theatre start. However, rates of cases performed in-hours were significantly increased in the ASU group.

Secondary outcomes

Introduction of an ASU was associated with fewer complications (Table 2). Improvements were observed in rates of appendiceal perforation, primary open appendicectomy, laparoscopic-converted-to-open appendicectomy and consultant scrubbed for procedure. There were no changes in rates of ICU admission nor ED representation within 30 days. There were no inpatient deaths in either group.

Figure 1. Patients undergoing an emergency general surgical procedure, by time period, type and completeness of data (aka eligibility).



4. DISCUSSION

The ASU model holds great promise for both patients and staff. It may also offer net savings for hospitals (162). Following first Australian implementation in 2005 (190), eleven hospitals nationally have reported their outcomes using this structure (51, 128, 157, 162, 163, 166, 191-196, 198, 200). This may represent under-reporting, or reluctance to change due to concerns over the ASU model's benefit, cost or suitability to a particular institution (221). Larger studies such as this which demonstrate an improvement in patient outcome, may provide encouragement to policy makers and hospitals still employing a Traditional model. The authors believe the multiple observed improvements related directly to greater theatre access and consultant availability to supervise both operative and non-operative care.

After-hours operating is known to carry a higher risk of surgical error and patient morbidity (222, 223). Accordingly, a key aim when introducing an ASU has been to increase the proportion of in-hours procedures. In our study, this proportion was significantly higher during the ASU period. This is in keeping with the findings of most (191, 193-195, 198, 200) but not all (128, 192, 196) other Australian ASU appendicectomy studies.

The ASU model has been variably shown to reduce time to reach theatre and length of stay. However, appendicectomy is typically given a more urgent triage category, reaches theatre within eighteen hours and has a length of stay of two to three days (212). This leaves less capacity for further improvements under an ASU model. Accordingly, this study found no change in median length of stay. Similarly unchanged length of stay has been reported all Australian ASU appendicectomy studies, without exception (128, 155, 191, 193-196, 198, 200). The combination of the modern understanding of the safety in delaying appendicectomy timing < 24 hours (224) and of the risk of overnight operating while fatigued (223, 225) combined with reliable morning theatre availability in the ASU model has led to a shift in practice. Previously routinely operated on during their first evening in hospital, patients are now routinely scheduled for appendicectomy the following day. This practice may negate other measures to reduce length of stay.

In this study, median time from ED referral to theatre start was unchanged under the ASU model. Inter-study comparison of time to theatre is challenging, due to widely varying timing start points, including a presentation to the ED, admission or entry on theatre bookings software (163). Accepting these limitations, Australian ASU appendicectomy studies have most commonly found time to theatre to be unchanged (128, 155, 191, 194, 196) or slower (192, 198, 200), with only Beardsley *et al.*’s cohort totalling 150 patients reporting improvements (195).

Complication rates in our institution were significantly lower during the ASU period, at 6%. Similar improvements have been reported by some (191, 196, 212), but not all Australian ASU appendicectomy studies (193, 194, 200). These reported ASU-period complication rates ranged 5.3 - 9.3% (191, 196, 200), rising to 10.3% in Nagaraja *et al*.'s systematic review that included international studies (212). There are multiple opportunities for complication reduction via the ASU model. Potential benefits include greater consultant supervision, reduced time to both non-operative measures and theatre, and reduced length of stay with corresponding decreased exposure to healthcare errors or nosocomial infections. The variation in reported effect of the ASU model on complications will therefore be determined by the ASU's impact on the above intermediary outcomes, as well the patient population, pathology studied and hospital factors.

Rates of intensive care unit admission and of ED representation within 30 days may also offer an indirect assessment of the quality of care. Neither index changed during the ASU period, a finding consistent with the other few Australian ASU appendicectomy studies reporting these outcomes (191, 193).

A useful additional benefit of the ASU model's dedicated staff and theatre resources is increased capacity. In our study, patient load was markedly higher during the ASU period. The authors believe development of an ASU increased our institution's capacity to treat these emergency presentations, without sacrificing (and in some areas improving) the quality of care provided. While increased patient load compared to earlier years might be expected, this has not been the case in some ASU cohorts (41, 51, 126, 128, 195). For those ASUs that did experience greater throughput, equivalent or superior results for the three key outcomes of time to theatre, daytime operating and length of stay were maintained by most (40, 120, 121, 125, 128, 155, 157, 160, 163, 166, 191, 193, 194, 196, 199) but not all sites (198, 200).

Limitations of this study include its retrospective nature and reliance on electronic medical records data. This latter risk was mitigated by manual interrogation of >1% of patient records across every data point, and of every patient record for eligibility and complication data. Separately, complications may have not been detected if wound infections were recorded in case notes but not discharge summary, or if they caused representation to a general practitioner or the ED without readmission. Greater than 20% of patient records were not included due to incomplete data, which may bias the results. A separate publication regarding the same time periods at our institution but grouping patients regardless of pathology found that eligible patient rates in both periods were similar, at 78 vs. 79% (163). The disparity in this appendicectomy subset is greater, and we are unable to rule out unmeasured confounding. However, removing this data caused minimal change to Traditional and ASU group sizes relative to each other. Another limitation is potential time shift bias, due to the more recent time period in the ASU group. While it is possible that some of the benefits could have been seen anyway with a more modern cohort regardless of ASU implementation, the authors feels this is unlikely as the time periods were immediately adjacent. Lastly, rates of consultant scrubbed in theatre do not take into account the possibility of consultants supervising in theatre while being unscrubbed and hence unrecorded on ORMIS.

Conclusion

This represents the second largest Australian appendicectomy cohort to date investigating the ASU model. Increased patient load was observed during the ASU period. Despite this, key outcomes including rates of in-hours operating and complications were improved, while other outcomes were unchanged. These findings extend the literature in support of this model of care for emergency general surgical patients.

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DISCLOSURE STATEMENT

Ned Kinnear received a University of Adelaide Divisional Scholarship in relation to this work. There was no other funding, and the authors have no conflicts of interest to declare.

Table 1. Patient demographics and outcomes.

	Traditional period	ASU period	P value
Demographics			
Patients	465	749	-
Female (%)	257 (55%)	419 (56%)	0.82
Median age (IQR) (years)	29 (22-40)	30 (23-43)	0.13
ASA 1 (%)	277 (60%)	417 (56%)	0.38
ASA 2 (%)	174 (37%)	304 (41%)	†
ASA 3 (%)	14 (3%)	28 (4%)	†
Primary outcomes			
Median length of stay (IQR) (days)	1.81 (1.44-2.83)	1.81 (1.38-2.78)	0.54
Median time ED OT (IQR) (days)	0.59 (0.29-0.86)	0.56 (0.27-0.82)	0.14
Cases performed in-hours (%)	337 (72%)	589 (79%)	0.014
Secondary outcomes			
In-hospital complications (%)	41 (9%)	42 (6%)	0.016
In-hospital mortality	0	0	-
Appendiceal perforation rate (%)	52 (11%)	39 (5%)	0.0001
Negative appendicectomy (%)	115 (29%)	219 (29%)	0.11
Primary open appendicectomy (%)	18 (4%)	5 (1%)	<0.0001
Lap. converted open appendicectomy (%)	29/447 (6%)	18/744 (2%)	0.0005
Consultant scrubbed for procedure (%)	99 (21%)	417 (56%)	<0.00001
ICU admission (%)	4 (1%)	8 (1%)	0.72
ED representation (%)	21 (5%)	41 (5%)	0.46

ASU: acute surgical unit. ED: emergency department. ED OT: emergency department referral to operating theatre start. ICU: intensive care unit. IQR: interquartile range. Lap: laparoscopic. %: proportion. †: a single Chi-squared test was performed comparing the distribution of each group's ASA scores. Hence, the p value of 0.38 implies similarly between each group's ASA distribution, as opposed to similar proportions of any single ASA score.

All proportions calculated using a denominator of the total number of patients in that period, with the exception of proportion of laparoscopic converted to open appendicectomies, where the denominator was number of cases commenced laparoscopically in that period.

Table 2. Complications of patients undergoing appendicectomy.

	Traditional period (n=465)	ASU period (n=749)
Total	41 (9%)	42 (6%)
Clavien-Dindo grade I		
Subcutaneous emphysema	2	-
Post-op. pain delaying discharge	4	-
Post-op. vomiting and/ or ileus	7	4
Post-op. persistent diarrhoea	1	-
Post-op. persistent fever	-	2
Clavien-Dindo grade II		
Wound infection	1	-
Post-op. collection managed conservatively	9	6
Urinary tract infection	1	3
Acute urinary retention	3	10
Pneumonia and/ or symptomatic atelectasis	-	3
Post-op. hypotension and/ or tachycardia	3	1
Arrhythmia, managed conservatively	2	1
Non-anaphylactic allergic reaction	1	2
Clavien-Dindo grade III		
Post-op. collection requiring drain insertion	1	3
Port site hernia, requiring return to theatre	1	-
Haemorrhage, requiring return to theatre	2	1
Intra-op. small bowel injury, primarily repaired	-	1
Clavien-Dindo grade IV		
Intra-op. laryngospasm, requiring ICU admission	2	-
Post-op. drowsiness, requiring ICU admission	1	-
Post-op. hypoventilation requiring ICU admission	-	1
Post-op. MI, pharmacologically managed	-	2
Post-op. hypotension requiring ICU admission	-	1
Intra-op. aspiration requiring ICU admission	-	1
Clavien-Dindo grade V		
In-hospital mortality	-	-

ASU: acute surgical unit. ED: emergency department. ICU: intensive care unit. MI: myocardial infarction. Op.: operative. -: zero.

Chapter 3: Publication 2

Communication and management of incidental pathology in 1,214 consecutive appendicectomies; a cohort study.

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ABSTRACT

Background: Important incidental pathology requiring further action is commonly found during appendicectomy, macro- and microscopically. We aimed to determine whether the acute surgical unit (ASU) model improved the management and disclosure of these findings.

Methods: An ASU model was introduced at our institution on 01/08/2012. In this retrospective cohort study, all patients undergoing appendicectomy 2.5 years before (Traditional group) or after (ASU group) this date were compared. The primary outcomes were rates of appropriate management of the incidental findings, and communication of the findings to the patient and to their general practitioner (GP).

Results: 1,214 patients underwent emergency appendicectomy; 465 in the Traditional group and 749 in the ASU group. 80 (6.6%) patients (25 and 55 in each respective period) had important incidental findings. There were 24 patients with benign polyps, 15 with neuro-endocrine tumour, 11 with endometriosis, 8 with pelvic inflammatory disease, 8 *Enterobius vermicularis* infection, 7 with low grade mucinous cystadenoma, 3 with inflammatory bowel disease, 2 with diverticulitis, 2 with tubo-ovarian mass, 1 with secondary appendiceal malignancy and none with primary appendiceal adenocarcinoma. One patient had dual pathologies. There was no difference between the Traditional and ASU group with regards to communication of the findings to the patient (p=0.44) and their GP (p=0.27), and there was no difference in the rates of appropriate management (p=0.21).

Conclusion: The introduction of an ASU model did not change rates of surgeon-to-patient and surgeon-to-GP communication nor affect rates of appropriate management of important incidental pathology during appendectomy.

Keywords: acute surgical unit, acute care surgery, appendicitis, appendicectomy, incidental, unexpected.

1. INTRODUCTION

Globally, appendicectomy is consistently the first or second most common emergency general surgical procedure (41, 45, 155, 163, 215). Unexpected findings occur in 3-14% of patients undergoing appendicectomy (226-229). Reported important macroscopic incidental pathologies include diverticulitis, endometriosis, inflammatory bowel disease, Meckel's diverticulitis, pelvic inflammatory disease and tubo-ovarian mass (226, 230-238). Similarly, reported incidental microscopic pathologies include benign polyps, endometriosis, Enterobius vermicularis or schistosomal infection, neuro-endocrine tumour and primary or secondary malignancy (226-228, 230-236, 238-245). However, most studies only detail the microscopic histopathological incidence, with only a handful describing patient management and follow-up (226, 227, 235, 246-248).

Separately, the acute surgical unit (ASU) model has enjoyed broad uptake in Australasia since its introduction 2005 (190). Compared with the Traditional model of managing emergency general surgical referrals, the ASU provides an on-site registrar, on-call consultant and ready emergency theatre, all available 24 hours a day. The core objectives of this model are faster patient care and a reduction in after-hours operating. Centres introducing the ASU model have routinely reported achieving these benefits, as well as fewer complications, improved staff satisfaction and reduced cost (155, 162, 163, 166, 249).

In our metropolitan tertiary referral hospital, staffing for emergency general surgical presentations changed from the Traditional to the ASU model on 01 August 2012. While improved patient disclosure and follow-up was not a pre-defined objective of this transition, the authors hypothesised that the greater provision of staffing specific to emergency general surgery would improve disclosure and follow-up. Hence, this study aims to assess whether the introduction of an ASU impacted the communication and management of important incidental pathology in patients with important incidental findings during appendicectomy at our site.

This investigation was stimulated by local quality and safety initiatives, and an appreciation of the paucity of relevant literature. Despite numerous studies of the ASU model, to date none have examined the frequency of incidental pathology following appendicectomy or any procedure, nor the impact of the new model on its communication or management (41, 153, 155).

2. MATERIALS AND METHODS

In this retrospective cohort study, all adult patients undergoing appendicectomy at our institution during the Traditional (01/02/10 – 31/07/12) and ASU periods (01/08/12 - 01/02/15) were enrolled. Eligible patients were aged ≥18 years, underwent appendicectomy (Medicare Benefits Schedule code 30571 or 30572) and had complete data available. Patients with incidental pathology were identified from their operation note or histopathology report. Data were collected by interrogation for every appendicectomy patient of the above documents, as well as their discharge summary. Hard copy medical records were also assessed for all patients with incidental pathology. Primary outcomes were rates of documentation of communication of important incidental findings to the patient within three months, to their GP within three months, and rates of documentation of appropriate management or follow-up within six months.

Important incidental pathology was defined as findings, either macroscopic intra-operatively or microscopic on subsequent histopathology, which required additional treatment or follow-up, or referral to a non-general-surgical speciality. Satisfactory communication to the patient of important incidental macroscopic findings required documentation of informing the patient during their index admission. Satisfactory patient communication of important incidental microscopic findings required documentation of its mention within three months during a scheduled outpatient consultation. When an outpatient consultation was scheduled but the patient failed to attend, communication to the patient and appropriate follow-up were recorded as satisfactory.

Satisfactory communication to the patient's GP of important incidental pathology required either its mention in the index admission discharge summary (which are automatically posted to the GP), or evidence in the hard-copy notes of its mention within three months in an outpatient letter or multi-disciplinary team (MDT) meeting letter addressed to the GP. Appropriate care for each condition was guided by the literature and relevant guidelines (Table 1). Instances where patients received some, but not all, of the recommended care items for their pathology were assessed as either satisfactory or not through inter-author discussion. Macroscopic findings of retrograde menses, ovarian cyst rupture, and unruptured ovarian cysts <3cm were assessed as needing no specific follow-up, and not included in this study.

We have previously described our acute surgical unit structure, handover routine and preliminary results (51, 153, 163). This study was performed in accordance with the Declaration of Helsinki and reported in line with the STROCSS criteria (250). This trial was logged with the Australian New Zealand Clinical Trials Registry (ACTRN12619000857101). Ethics approval was obtained (see Author Disclosure Statement).

2.1 Statistical analysis

Continuous data with non-parametric distribution (patient age) were summarized as medians with interquartile range (IQR), and significance assessed using the Wilcoxon (Mann–Whitney) test. Continuous data with parametric distribution were summarised as means with standard deviation (SD) and significance assessed using Student's t-test. Categorical measures were summarized as proportions and assessed with Pearson's chi-square test. All tests were two-tailed, and significance was assessed at the 5% alpha level.

3. RESULTS

3.1 Demographics

In the enrolment period, 1,214 eligible patients underwent appendicectomy, with 465 and 749 patients in the Traditional and ASU periods respectively. The cohorts were similar in gender, median age and American Society of Anaesthesiologists physical status score 1. However, there was a significant trend towards more severe laparoscopic appendicitis grade in the Traditional cohort (251) (Table 2).

3.2 Primary outcomes

Important incidental pathology was found in 80 patients; 25 (25/465; 5.3%) and 55 (55/749; 7.3%) in the Traditional and ASU periods respectively. These included 15 (1.2%) with neuro-endocrine tumours, 11 (0.9%) with endometriosis, 8 (0.7%) with *Enterobius vermicularis* infection, 8 (0.7%) with pelvic inflammatory disease, 7 patients (0.6%) with low grade mucinous cystadenomas and 3 (0.2%) with inflammatory bowel disease (Table 2). All patients had a single pathology except for one patient in the ASU period, whose appendiceal histology revealed both endometriosis and a low-grade mucinous neoplasm. No patient had missing outcomes data.

When important incidental pathology was detected, more than three-quarters of patients were informed within three months, without a significant difference between the two periods (84% vs. 76%; p=0.44). Both groups had similar rates of correspondence within three months to the patient's general practitioner regarding the incidental pathology (84% vs. 73%; p=0.27). Lastly, rates of appropriate management within six months of important incidental pathology were equivalent (84% vs. 71%; p=0.21) (Table 2).

The twenty patients who did not receive appropriate prompt treatment comprised five patients with sessile serrated adenomas (SSA), four with *Enterobius vermicularis* infection, four with endometriosis, three with neuro-endocrine tumours, two with low grade (LG) tubular adenomas, one with LG mucinous cystadenoma and one with suspected inflammatory bowel disease (Table 3). Only three of these patients were informed of their pathology, named one each with SSA, LG tubular adenoma and LG mucinous cystadenoma. Seventeen patients had no further management of any kind, while three patients had partial but inadequate or unrelated further care. Specifically, one patient with LG mucinous cystadenoma (non-perforated and without extra-appendiceal mucin) declined colonoscopy, was not referred to MDT and was discharged and a second with neuro-endocrine tumour was investigated one year later for per rectal bleeding with an unremarkable colonoscopy. A third and final patient with an appendiceal SSA had a colonoscopy three years later following positive screening faecal occult blood test, with the finding of multiple polyps leading to elective total colectomy.

4. DISCUSSION

Contrary to this study's hypothesis, introduction of an ASU was not associated with improvements in communication or management of important incidental pathology in patients undergoing appendicectomy. While the management of twenty patients fell below accepted standards (Table 4), some of these omissions held more consequence than others. In ten (e.g. half) of these patients, the failure to obtain ideal management likely held minimal harm. Specifically, the three patients with appendiceal neuro-endocrine tumour received curative resection, and the accepted standard of care that they lacked (MDT discussion) would have added little. Similarly, case note review (data not shown) revealed that the three patients with microscopic evidence of endometriosis were not otherwise symptomatic from this disease. Finally, while four patients had evidence of Enterobius vermicularis infection, this disease is often cleared by the host, is well suited to community-based detection and has no reported deaths in Australia. In contrast, for ten patients, certain investigations or referrals would have been advantageous. This included the seven patients with appendiceal mucosal adenomas, who warranted colonoscopy for their elevated risk of synchronous colonic polyps. Similarly, the patient with a low grade mucinous neoplasm with mucin extending into the meso-appendix would have been more comprehensively managed with serum tumour markers, contrast computed tomography scan of the abdomen and pelvis, and referral to a multi-disciplinary team meeting. Lastly, the two patients with macroscopic evidence of endometriosis or Crohn's disease respectively clearly had symptomatic disease, and warranted specialist referral.

Patient communication is a cornerstone of surgical practice and non-technical skills (252). However, little research exists objectively measuring communication rates of outcomes in emergency general surgery. To locate relevant studies, a literature review was performed using databases Medline, Embase and the Central Register of Controlled Trials. These searched the titles and abstracts of English language studies published from any date prior to 21 February 2019. Search terms were (appendicectomy OR cholecystectomy OR hernia OR general surgery) AND (communication OR disclosure) AND (patient OR general practitioner OR family physician OR family doctor OR family practitioner OR local medical officer). From 764 total results including 533 unique studies, five full text articles were reviewed. Of these, a single quantitative study in general surgery was identified concerning post-operative surgeon-to-patient or surgeon-to-general practitioner communication. This British retrospective study assessed patients undergoing laparoscopic surgery for right iliac fossa pain (253). Amongst the 55 patients who returned the questionnaire, 100% reported being informed of their intra-operative diagnosis as either an in- or out-patient, although written record of this disclosure existed for only 14%. Furthermore, five of 55 patients were unsure if their appendix had been removed, and two of twelve patients with important incidental pathology were unsure of their diagnosis. These findings highlight the potential for improvement in all of clinician communication, consult recording and patient information retention.

Incidental detection of important pathology behoves appropriate management. However, very few appendicectomy series confirm that this occurred (226, 227, 235, 246-248). Safety net systems to ensure patients receive adequate care necessarily differ depending on the timing of detection. Macroscopic pathology detected intra-operatively relies on the punctual post-operative action of the scrubbed registrar and consultant. Microscopic pathology, on the other hand, takes several days to process and so requires a different approach. Options for capture include assigning the responsibility for pathology checking to the involved proceduralists, a single catch-all surgical staff member, the outpatient clinic, an automated letter-to-patient from the histology laboratory (254) or a combination of the above. Macro- or microscopic, strong and robust measures are necessary to ensure incidental pathology is not missed. The rates of appropriate management observed in this study were lower than expected. This study has subsequently prompted our department to re-emphasise the importance of each staff member regular reviewing and acting on pathology results.

Adequate communication with a patient's general practitioner is essential for patient care. It provides a safety net if patients fail to pursue recommended management, reduces double treatment if they are unclear this has already occurred and empowers the GP as the coordinator of the patient's care (255). Increased collaboration with GPs has been associated with positive outcomes in a wide range of conditions, including cancer care and medication-related unplanned hospital admission (256, 257). However, no studies to date have described GP communication rates following appendicectomy. Post-operatively, every GP should receive a discharge summary, and also later an outpatient letter for those patients reviewed in clinic. General practitioners place a high value on promptly receiving discharge summaries, including following general surgery (258). However, disseminating a summary shortly after discharge means histopathology results will not be available for many patients. This was indeed the case in this study. The responsibility, therefore, lies on either the conscientious checking of the proceduralist some days post-operatively, as above, or the inpatient team to book an outpatient appointment. Future additional fail-safes could include routine dissemination of pathology to GPs, separate to the discharge summary.

The observed rate of significant incidental pathology was generally similar to other large series of >1,000 patients (226-228, 230-242, 244, 245) (Table 4). Two notable variants in our cohort from the literature were our relatively high rate of benign adenomas of any type, at 2.0% (literature pooled mean 0.2%). However, most studies reported only a single type of adenoma (either tubular, villous or sessile serrated), which when construed to represent the pooled rate of all adenomas would tend to underestimate the true rate. Yuyucu Karabulut et al.'s study of 960 appendicectomies included a comprehensive range of adenomas, with a pooled adenoma incidence of 7.4% (243). Endometriosis was also more common in our study than expected from the literature. Endometriosis incidence is known to vary considerably both between different nations, and different populations within the same nation. Risk factors for endometriosis include early age of menarche, being of reproductive age, nulliparity and short heavy menstrual cycles (259, 260). Our retrospective cohort may have sampled from a more at-risk population. Indeed, South Australia has been reported as having a >2x higher prevalence of endometriosis than other Australian states (261). Alternatively, it has been suggested that endometriosis incidence is overestimated amongst reproductive age women hospitalised for abdominal pain (259). As five of our cohort's eleven cases of endometriosis were macroscopic diagnoses unsupported by histology, such bias may be present.

This study is limited by its retrospective nature and the relatively small number of patients with important incidental pathology. While the cohorts were superficially demographically statistically similar, there may have been unmeasured differences between the two periods in patient socioeconomic status, ethnicity and comorbidity which affected the incidence of pathology. Enrolment utilised electronic medical records data, which may have been incorrectly coded. This reliance was reduced by manual examination of the medical records of >1% of the total cohort 1,214 patients, and of every hard copy record for the 80 patients with incidental findings data. Additionally, enrolling patients based on MBS codes means that this study did not capture procedures which commenced with the intention to perform appendicectomy, but then changed intra-operatively due to incidental pathology to a different procedure such as hemicolectomy, small bowel resection or salpingo-oophorectomy. Separately, greater than 20% of patient records were not included due to incomplete data, which may bias the results. However, the exclusion was balanced between the Traditional and ASU groups and caused minimal change in group sizes relative to each other. The authors have previously reported satisfactory use of this practice (153, 163). Lastly, it is possible that for some patients, communication did indeed occur, but only verbally, or via posted documentation but without a separate copy being filed in the hard copy case notes. This may have reduced the observed rate of communication to the patient and GP.

4.1 Conclusion

Introduction of an ASU model did not change documented rates of surgeon-to-patient nor surgeon-to-GP communication nor affect rates of appropriate management of important incidental pathology during appendicectomy.

CONFLICTS OF INTEREST

None to declare.

Please refer to Author Disclosure Statement for details on Ethics, Funding, Study Registration, Acknowledgements and Author Contribution.

Table 1. Optimal management criteria for important incidental pathology from appendicectomy.

Condition	Management
Appendiceal neoplasms - Primary	
Epithelial	
Benign	
Serrated sessile adenoma	Colonoscopy in <6 months, or 5 years from last, whichever is later † (262, 263).
Low grade tubular adenoma	Colonoscopy in <6 months, or 5 years from last, whichever is later † (262, 263).
Low grade villous adenoma	Colonoscopy in <6 months, or 3 years from last, whichever is later † (262, 263).
Malignant	
Low grade mucinous neoplasm	Counseling of diagnosis. MDT discussion. No follow-up in most (264, 265). If both appendiceal perforation and extra-appendiceal mucin are present, offer serum tumour markers, CT AP and referral to a specialist centre ‡ (264). If appendiceal perforation but not extra-appendiceal mucin is present, and lesion is macroscopically removed, offer colonoscopy, and serum tumour markers § and CT AP annually (264).
High grade mucinous neoplasm/ adenocarcinoma	Counseling of diagnosis. Colonoscopy in <6months. MDT discussion. If completely resected pathologic stage T*is* or favourable risk T1, offer repeat colonoscopy in 12 months. If incompletely resected, high risk T1 (high grade atypia, lymphovascular invasion) or T2≤, offer CT AP and right hemicolectomy (264, 266, 267).
Non-epithelial	
Neuro-endocrine tumours	Counseling of diagnosis. MDT discussion. No follow-up in most || (268). Offer right hemi-colectomy if any of: lesion >2cm, positive margin or involves meso-appendix ¶ (264, 268, 269). These patients require long-term follow up.
Appendiceal neoplasms - Secondary	
Melanoma	Counseling of diagnosis. CT AP. MDT discussion. Cutaneous examination for primary. Proceed based on findings.
Non-appendiceal - Gynaecological	
Endometriosis	Referral to gynaecology.
Pelvic inflammatory disease	Testing for sexually transmitted infection. Empiric antibiotic therapy with ceftriaxone, metronidazole and azithromycin †† (270). Referral to gynaecology to confirm clearance and discuss fertility implications.
Tubo-ovarian mass	Referral to gynaecology ‡‡.
Non-appendiceal – Other	
Large bowel diverticulitis	Minimum five days of antibiotic therapy (271). Offer colonoscopy (272).
Crohn's disease	Referral to gastro-enterology §§.
Enterobius vermicularis infection	Anthelmintics (e.g. mebendazole, albendazole, pyrantel) oral single dose (273).

Appendiceal neoplasm classification in keeping with Murphy *et al*. (264).
CT AP: computed tomography scan abdomen/ pelvis. MDT: multi-disciplinary team. NET: neuro-endocrine tumours.
†: Joint Australian guidelines recommend that when adenomas are resected but the colon has not been fully cleared of adenomas, then colonoscopy be performed 3-6 months post-op (263). For low grade tubular adenomas and sessile serrated adenomas, these guidelines recommend repeat colonoscopy at 5 years. For adenomas with villous features or high grade dysplasia, these guidelines recommend repeat colonoscopy at 3 years (262).
‡: To consider cytoreductive peritonectomy and heated intraperitoneal chemotherapy, to reduce the risk of developing pseudomyxoma peritonei syndrome (264).
§: Colorectal tumour markers include carcinoembryonic antigen, cancer antigen-125 and cancer antigen-19-9
||: For NETs not meeting criteria for hemicolectomy, follow-up is controversial. Options include surveillance CT AP, urine 5-hydroxyindoloacteic acid or serum chromogranin-A. Guidelines do not recommend specific follow up (268).
¶: Additional histological factors supporting right hemicolectomy include high mitotic index (≥2 mitoses per mm^2), high Ki-67 index (≥2% cells staining positive for Ki-67), lymphovascular invasion, involved lymph nodes, adenocarcinoid type and moderate or high grade atypia (264, 269).
††: Antibiotic route and duration tailored to disease severity (270).
‡‡: Tubo-ovarian masses include hydro-salpinx, ectopic pregnancy and suspected ovarian mass. These should ideally be referred intra-operatively. Gynaecological workup may include pelvic ultrasound, and serum tumour markers beta human chorionic gonadotrophin, alpha fetoprotein and cancer antigen-125.
§§: For counseling and offering of gastroscopy/ colonoscopy to confirm diagnosis.

Table 2. Patient demographics and incidental findings.

	Traditional period (n=465)	ASU period (n=749)	P value
Female (%)	257 (55%)	419 (56%)	0.82
Median age (mean ±SD) (years)	29 (33 ±14)	30 (34 ±14)	0.13
ASA 1 (%)	277 (60%)	417 (56%)	0.38
ASA 2 (%)	174 (37%)	304 (41%)	†
ASA 3 (%)	14 (3%)	28 (4%)	†
Laparoscopic grade of appendicitis (45)			
0 - normal looking appendix	103 (22%)	166 (22%)	0.003
1 - inflamed appendix	268 (58%)	471 (63%)	†
2 - appendiceal necrosis, nil/ minimal peri-colic fluid	23 (5%)	40 (5%)	†
3 - phlegmon or abscess	18 (4%)	33 (4%)	†
4 - perforation, diffuse peritonitis or free air	53 (11%)	39 (5%)	†
Appendiceal neoplasms - Primary			
Epithelial			
Benign			
Serrated sessile adenoma	1	18	
Low grade tubular adenoma	0	4	
Low grade villous adenoma	0	1	
Malignant			
Low grade mucinous neoplasm	2	5 ‡	
High grade/ adenocarcinoma	0	0	
Non-epithelial			
Neuro-endocrine tumours	9	6	
Appendiceal neoplasms - Secondary			
Melanoma	0	1	
Non-appendiceal - Gynaecological			
Endometriosis	3	8 ‡	
Pelvic inflammatory disease	4	4	
Tubo-ovarian mass §	1	1	
Non-appendiceal – Other			
Large bowel diverticulitis	1	1	
Crohn's disease	2	1	
Enterobius vermicularis infection	2	6	
Total important incidental pathology (patients)	25 / 465 (5.4%)	55 / 749 (7.3%)	n/a
Outcomes			
Patient informed within 3 months	21 / 25 (84%)	42 / 55 (76%)	0.44
General practitioner informed within 3 months	21 / 25 (84%)	39 / 55 (71%)	0.21
Appropriate management or follow up within 6 months	21 / 25 (84%)	40 / 55 (73%)	0.27

ASA: American Society of Anesthesiologists physical status score. ASU: acute surgical unit. n/a: not applicable. SD: standard deviation. †: a single p-value applies to the difference between all the ASA or appendicitis grades for the two cohorts. ‡ : one ASU patient had both appendiceal histology revealing both a low grade mucinous neoplasm and endometriosis. § : includes hydro-salpinx, ectopic pregnancy, suspected ovarian mass. Does not include pyosalpinx, which is grouped with pelvic inflammatory disease.

Table 3. Incidental pathology during appendicectomy in series of >1,000 patients

	This cohort incidence (overall)	Literature incidence (mean†‡, N/D)	Range ‡ (min-max %)	Contributing studies
Appendiceal neoplasms - Primary				
Epithelial				
Benign - Any	2.0%	0.2% (66 / 26,522)	0.06 – 0.6%	7 (230, 232-234, 239, 241, 245)
Malignant				
LG mucinous neoplasm	0.6%	0.3% (181 / 56,962)	0.03 – 0.9%	10 (226-228, 231-234, 236, 239, 240)
HG/ adenocarcinoma	-	0.1% (53 / 58,392)	0.03 – 0.2%	10 (228, 230-234, 236, 239, 241, 245)
Non-epithelial				
Neuro-endocrine tumours	1.2%	0.4% (299 / 67,530)	0.09 – 1.0%	14 (226, 228, 230-236, 239, 240, 242, 244, 245)
Appendiceal neoplasms - Secondary				
Any	0.1%	0.05% (17 / 36,819)	0.00 – 0.2%	4 (232, 233, 237, 239)
Non-appendiceal - Gynaecological				
Endometriosis	0.9%	0.1% (32 / 37,425)	0.01 – 0.3%	6 (226, 232, 234-236, 238)
Pelvic inflammatory disease	0.7%	1.7% (21 / 1,232)	1.7% §	1 (237)
Tubo-ovarian mass ¶	0.2%	0.1% (3 / 3,755)	0.04 – 0.2%	2 (231, 235)
Non-appendiceal – Other				
Cholecystitis	-	0.2% (3 / 1,255)	0.2% §	1 (235)
Enterobius vermicularis infection	0.7%	4.1% (1,889 / 46,598)	0.04 – 6.5%	8 (226-228, 230, 234-236, 240)
Foreign body bowel perforation	-	0.04% (2 / 4,4,95)	0.03 – 0.1%	2 (230, 233)
Inflammatory bowel disease	0.2%	0.1% (45 / 53,458)	0.05 – 0.2%	4 (226, 230, 236, 237)
Large bowel diverticulitis	0.2%	0.8% (59 / 7,155)	0.1 – 1.6%	3 (230, 232, 233)
Large bowel malignancy ††	-	0.1% (2 / 2,660)	0.1% §	1 (232)
Lymphoma	-	0.1% (11 / 12,896)	0.01 – 0.3%	3 (226, 227, 239)
Meckel's diverticulitis	-	0.2% (9 / 4,152)	0.13 - 0.3%	2 (232, 233)
Peptic ulcer disease	-	0.1% (2 / 1,492)	0.1% §	1 (233)
Schistosomiasis infection	-	0.9% (48 / 5,344)	0.15 – 1.3%	2 (226, 240)
M. tuberculosis infection	-	0.2% (3 / 1,232)	0.2% §	1 (237)

D: denominator, summating series reporting at least 1 case of the relevant pathology. HG : high grade. LG: low grade. N: numerator, representing total number of patients with the relevant pathology. %: percentage. -: no cases.
†: pooled mean. ‡ : amongst series reporting at least 1 case. § : only a single series of >1,000 appendicectomies identified reporting this pathology. ¶ : includes hydro-salpinx, ectopic pregnancy, suspected ovarian mass. Does not include pyosalpinx, which is grouped with pelvic inflammatory disease. †† : not involving appendix.

Table 4. Incidental pathology patients without appropriate management

Condition		Pathological characteristics of incidental pathology
Appendiceal neoplasms - Primary		
Sessile serrated adenomas		
Patient 1	22yo female	NPA, MANA. No dysplasia identified. Completely excised.
Patient 2	25yo female	NPA, MAA. No dysplasia identified. Completely excised.
Patient 3	53yo female	NPA, MAA. No dysplasia identified. Completely excised.
Patient 4	65yo male	NPA, MAA. No dysplasia identified. Completely excised.
Patient 5	70yo male	NPA, MAA. Low grade dysplasia. Completely excised.
Low grade tubular adenoma		
Patient 6	29yo female	NPA, MAA. Microscopic LG TA with low grade dysplasia, completely excised.
Patient 7	68yo female	NPA, MANA. Microscopic LG TA without dysplasia, completely excised.
Low grade mucinous neoplasm		
Patient 8	63yo male	NPA, MAA. A low grade mucinous neoplasm is seen with dissecting acellular mucin in the muscularis propria and meso-appendix. The serosal surface and resection margin are not involved.
Neuro-endocrine tumours		
Patient 9	22yo male	NPA, MAA. 6mm well differentiated NET, extending through muscularis, but serosa not breached. Meso-appendix and surgical margin are not involved. LVI, mitotic index and Ki-67 index are not reported.
Patient 10	22yo female	NPA, MANA. 3mm well differentiated NET, confined to the lamina propria. Surgical margin is not involved. Ki-67 index is low (<2%). LVI and mitotic index are not reported.
Patient 11	27yo male	NPA, MANA. 7mm well differentiated NET, extending through muscularis, but serosa not breached. Meso-appendix and surgical margin are not involved. No evidence of LVI. Both mitotic index (≤2 mitoses per mm^2) and Ki-67 (<2%) index are low.
Non-appendiceal – Gynaecological		
Endometriosis		
Patient 12	21yo female	Not applicable – macroscopic diagnosis intra-operatively, no biopsy taken.
Patient 13	35yo female	NPA, MAA. Several foci of endometriosis are seen.
Patient 14	41yo female	NPA, MAA. One focus of endometriosis is seen.
Patient 15	68yo female	NPA, MAA. Several foci of endometriosis are seen.
Non-appendiceal – Other		
Crohn's disease		
Patient 16	19yo male	Not applicable – macroscopic diagnosis intra-operatively, no biopsy taken.
Enterobius vermicularis infection		
Patient 17	20yo female	NPA, MAA. Organisms are seen consistent with *Enterobius vermicularis*.
Patient 18	21yo male	NPA, MAA. Organisms are seen consistent with *Enterobius vermicularis*.
Patient 19	30yo female	NPA, MAA. Organisms are seen consistent with *Enterobius vermicularis*.
Patient 20	52yo female	NPA, MAA. Organisms are seen consistent with *Enterobius vermicularis*.

LG TA: low grade tubular adenoma. LVI: lympho-vascular invasion. MAA: meso-appendix attached. MANA: meso-appendix not attached. NET: neuro-endocrine tumour. NPA: non-perforated appendix. yo: year old.

Chapter 4: Publication 3

Impact of an acute surgical unit on outcomes in acute cholecystitis.

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Contribution to the Paper	Performed data analysis, wrote second draft, created tables and acted as corresponding author		
Overall percentage (%)	40%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
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ABSTRACT

Introduction: The acute surgical unit (ASU) model has been associated with improved outcomes for emergency general surgical patients. Few Australasian studies have investigated patients with cholecystitis, and none from South Australia.

Methods: A retrospective cohort study compared patients admitted to our institution with acute cholecystitis during the two years before (Traditional period) and after (ASU period) introduction of an ASU on 1 August 2012. Primary outcomes were length of stay, rates of definitive surgery on index admission, time to definitive surgery and proportion of cases performed in-hours. Secondary outcomes were time from emergency department (ED) referral to admission, time from radiologically confirmed diagnosis to theatre start, rates of conversion to open cholecystectomy, complications and cholelithiasis-related re-presentations whilst awaiting definitive procedure.

Results: 319 patients met inclusion criteria; 172 and 147 pre- and post-ASU introduction respectively. Compared with the Traditional period, ASU patients had shorter length of stay (3.80 vs. 2.83 days, $p<0.0001$), higher rates of surgery on index admission (70.9% vs. 95.3%, $p<0.0001$), shorter time to definitive surgery (28.1 vs. 22.1 days, $p<0.001$), lower rates of conversion to open cholecystectomy (18.0% vs. 7.1%, $p=0.007$) and fewer complications (24.4% vs. 6.1%, $p<0.0001$). Other outcomes were not significantly different.

Discussion: Introduction of an ASU was associated with superior outcomes amongst patients admitted with acute cholecystitis. These findings extend the literature in support of the current model of care.

Keywords: acute surgical unit, cholecystectomy, cholecystitis, emergency surgery, general surgery.

INTRODUCTION

Acute cholecystitis is a common emergency general surgical condition. This pathology was initially regarded as a contraindication to laparoscopic cholecystectomy (274, 275). However, level I evidence demonstrated early cholecystectomy to be safe, and offer reductions in rates of conversion to open surgery, complications, length of stay and cost (276-278).

Traditional models of managing non-elective general surgical presentations allocated call to a rotation of general surgical units. Registrars would see patients in between outpatient and operative commitments. Similarly, consultants had scheduled duties and were not consistently available. Operations would wait until the end of elective lists, or earlier at the expense of rescheduled elective operating.

The acute surgical unit (ASU) model was pioneered in Australia in 2005 (121, 190, 191, 197). It has since spread throughout Australia (120, 128, 157, 160, 166, 192-194, 196) and New Zealand (159, 203, 204). The central tenets of an ASU comprise an on-site registrar, on-call consultant and dedicated emergency theatre, all committed solely to managing emergency general surgical presentations and available 24 hours per day.

Several studies have demonstrated the benefits of this model in appendicitis (128, 191-194, 196, 204), small bowel obstruction (197) and generically (157, 159, 166, 190, 203). However, to date only seven Australasian studies totalling <2,100 patients have examined outcomes in those with cholecystitis (120, 121, 125, 126, 128, 155, 160). These have reported mixed results in achieving surgery on index admission, as recommended by Cochrane review (276). The Lyell McEwin Hospital is a tertiary referral hospital in South Australia. On the 1st of August 2012 the traditional system of managing non-elective general surgical referrals was transitioned to an ASU model (163). This study aims to compare outcomes between models for patients admitted with acute cholecystitis. The authors hypothesised that ASU introduction would lead to improvements in the proportion of patients receiving surgery on index admission, time-based system performance indicators and complications.

METHODS

A retrospective cohort study was performed at our institution, comparing the traditional (1 August 2010 to 31 July 2012) and ASU periods (1 August 2012 to 31 July 2014). Eligible patients were adults aged ≥18 years admitted with radiologically confirmed discharge diagnosis of acute cholecystitis. Patients were excluded if surgery was not indicated, due to patient preference, unfit for general anaesthetic or palliation. Hard-copy case notes were examined for all patients. Patients were followed up for 365 days by repeat patient record review. Primary outcomes were median length of stay, rates of definitive surgery on index admission, median time to definitive surgery, and proportion of cases performed in hours (0800 – 1700). Secondary outcomes were median time from emergency department (ED) triage presentation to admission, median time from radiologically confirmed diagnosis to theatre start time, rates of intra-operative conversion to open cholecystectomy, complications and representation with cholelithiasis-related pathology whilst awaiting definitive procedure, specifically biliary colic, cholecystitis, choledocholithiasis or gallstone pancreatitis.

Ultrasound or computed tomography imaging was accepted as radiological confirmation. Time of radiologically confirmed diagnosis was the time at which the patient had received both imaging as defined above, and review by the ASU registrar, regardless of which occurred first. This included patients presenting with prior outpatient imaging. Analyses of proportion of cases performed in hours, time from triage or diagnosis to theatre start and conversion rates were performed only for patients undergoing cholecystectomy on index admission.

We have previously published our unit structure, including staffing hours and theatre access (163). Handover occurs twice daily for 30 minutes each. Morning handover begins at 0730 on weekdays and 0800 on weekends, and all aforementioned staff are present. All patients admitted in the preceding 24 hours are discussed. Patients with sub-specialty specific pathology or post-operative complications are handed over to the relevant specialty. Those with generic conditions such as cholecystitis, small bowel obstruction or trauma remain under the care of the on-call consultant from the concluding 24-hour period. The ASU ward round immediately follows the morning handover, and the on-call consultant reviews every patient. The evening handover commences at 2000, with the ASU registrar and junior registrar communicating via telephone with the on-call consultant.

Every cholecystectomy is supervised by either an in-theatre consultant, fellow or senior registrar. Of the ten ASU surgeons, all perform routine intra-operative cholangiogram except one, who performs selective cholangiogram. The proportion of on-call by this latter consultant was the same in both periods. Representations were managed on a case-by-case basis. After re-assessment including consideration of repeat imaging, where possible patients with ongoing cholecystitis symptoms were given antibiotics and analgesia. To reduce surgical morbidity, our preferred operating periods in cholecystitis are within 72 hours of symptom onset, or six weeks later. This approach is the unanimous consensus amongst the ASU surgeons, rather than a formal pathology-specific protocol, which are not used by our unit.

Continuous data were summarised as both medians and means, with significance assessed using the Wilcoxon (Mann-Whitney) test. Categorical measures were summarized as proportions and assessed with Pearson's Chi-square test. Data were analysed using Prism software version 5.01 (GraphPad Software Inc., La Jolla, California, United States of America). All tests were two tailed and significance was assessed at the 5% alpha level.

Ethics approval was granted by the Central Adelaide Local Health Network Human Research Ethics Committee, reference HREC/14/TQEHLMH/148. The authors have no conflicts of interest to declare. Writing of this study was conduced in accordance with the Strengthening The Reporting of Observational Studies in Epidemiology checklist.

RESULTS

319 patients met enrolment criteria; 172 and 147 during the Traditional and ASU periods respectively. There were no significant differences between the groups in median age (48 vs. 44 years, p=0.06) nor gender (65.1% vs. 62.8% female, p=0.67).

All patients underwent cholecystectomy within 365 days of presentation. All case notes were able to be obtained, with no missing data.

Compared with the Traditional period, patients admitted with cholecystitis during the ASU period had superior median length of stay (3.80 vs. 2.83 days, p < 0.0001), proportion of patients receiving definitive surgery on index admission (70.9% vs. 95.3%, p < 0.0001) and median time to definitive surgery (28.1 hours vs. 22.1 hours, p < 0.0001). The proportion of cases performed in-hours was higher, but this did not reach significance (87.7% vs. 92.9%, p = 0.08) (Table 1, Table 2**).**

Introduction of the ASU was also associated with significantly lower rates of conversion to open cholecystectomy (18.0% vs. 7.1%, p = 0.007) and complications (24.4% vs. 6.1%, 0 < 0.0001). There were no instances of bile duct injury nor in-hospital mortality in either time period. The remaining secondary outcomes were all non-significantly improved. These included median time from ED presentation to admission (5.19 vs. 4.50 hours, p = 0.13) and median time from radiologically confirmed diagnosis to theatre start (23.3 vs. 21.6 hours, p = 0.16).

Seventeen of the fifty patients (34.0%) in the Traditional period not receiving definitive procedure during their elective admission represented with cholelithiasis-related pathology whilst awaiting definitive procedure. Similar representation occurred in only one of the seven (14.3%) patients with deferred procedure in the ASU period.

DISCUSSION

Gallstone disease is one of the most common general surgical presentations. In Western nations, >10% of adults have biliary calculi, with higher rates seen in females and with increasing age (279, 280). Approximately 30% will become symptomatic and require cholecystectomy (280, 281). A plethora of evidence has shown laparoscopic cholecystectomy superior to the traditional open technique (277, 282), and yet to be superseded by the robotic method (283). Wide acceptance has led laparoscopic cholecystectomy to become one of the most frequently performed operations, with over 49,000 and 500,000 cases occurring annually in England and the United States of America respectively (281, 284).

As a common presentation with a clear mandate for surgery (276-278), cholecystitis represents an excellent yardstick against which to measure the improvement of hospital systems. With dedicated staff and theatre access, establishing an ASU can reasonably be expected to increase rates of definitive surgery on index admission and decrease time-based performance indicators. This was indeed the case in our institution. Median length of stay improved, supporting the findings of four Australasian studies of the impact of an ASU on cholecystitis outcomes (121, 125, 126, 160). Other similar studies have found no change (128), or stated improvement without confirming statistical significance (120). Shorter length of stay is a tangible improvement for the patient and reduces health care costs (285).

Both a Cochrane review and a subsequent retrospective study of 1,710 patients recommend laparoscopic cholecystectomy on index admission (276, 284). In this study, introduction of an ASU was associated with achieving this gold-standard more frequently. The authors believe this was directly related to improved access to theatre and surgeon availability. Similarly improved cholecystectomy rates on index admission have been reported in some (125, 160) but not all (120, 126, 128) Australian ASU studies. Additionally, median time to definitive surgery was lower for ASU patients, supporting the findings of the sole prior study to report this metric (160).

The proportion of cases performed in-hours was higher in the ASU period, however this was not significant. This is likely due to the high baseline proportion of 87.7% in the Traditional period, exceeding the 60 – 80% of other centres pre-ASU (120, 126, 128, 160). The small number of patients who received delayed cholecystectomy were those for whom clinical or logistical factors did not allow a procedure within 72 hours of symptom onset. These patients were offered either ongoing inpatient waiting for a procedure, or discharge with an elective cholecystectomy booking in six weeks.

The association between sleep deprivation and both poorer laparoscopic dexterity and higher surgical mortality has been well-demonstrated (222, 223, 225). The high rate of in-hours operating observed in the ASU period minimises these risks. Moreover, resource availability may influence management. Radiographers rostered overnight in this institution are often not qualified to perform intra-operative cholangiograms. Laparoscopic cholecystectomy may be deferred until the following day if a cholangiogram is not available. Wider training in this procedure may enable an optimal balance between the majority of cases being performed in the daytime hours, and the safer performance of after-hours procedures when required.

The discrete time segments of the journey from presentation to discharge of the patient with cholecystitis have been reported in several ASU analyses. The interval from surgical review to theatre start has inconsistently shown improvement in association with introducing an ASU (120, 121, 125, 126, 128). This may be due to hospital variation in the availability of confirmatory ultrasonography, which is typically required before proceeding to theatre. To avoid this bias, this study measured the time from radiologically confirmed diagnosis to theatre start. Unexpectedly, this duration was not improved. Most patients in both the Traditional and ASU periods who received cholecystectomy on index admission did so on the day following their diagnosis. This may be due to cholecystitis routinely being viewed as a lower priority than other general surgical procedures such as appendectomy and abscess debridement. The aforementioned after-hours difficulty in obtaining a cholangiogram may act as a deterrent to nocturnal procedures.

Complication rates were significantly lower in the ASU period. This was likely related to the more comprehensive supervision provided by the new staffing arrangements, particularly the round the clock guidance of a consultant surgeon. Similar reductions in peri-operative morbidity associated with greater specialist supervision have been reported in non-elective colorectal and trauma surgery (286, 287). Additionally, the dedicated ASU registrar's repeated experience with common presentations reduces iatrogenic error, and reduced length of stay decreases the time the patient's exposure to nosocomial risks. Our observed ASU complication rate of 6.1% compares well with the 6.4 - 8.7% reported by other Australasian ASU cholecystectomy series (121, 125). In the same vein, the reduced conversion rate of 7.1% supports the 1.7 -

7.1% of other ASUs (121, 128, 160), and lies below the typical 10% of non-elective laparoscopic cholecystectomy in other Australian tertiary centres (284, 288). As do other authors, we attribute this to a higher proportion of patients were receiving definitive surgery before the development of severe inflammation can necessitate conversion (278, 285, 289).

Representations related to cholelithiasis whilst awaiting definitive surgery are well known. Typical rates are 7 - 14%, which rise further proportional to the duration spent waiting (285, 289). The lower number of representations associated with the ASU can be expected to alleviate the workload of emergency and surgical staff, and decrease healthcare costs.

The moderate sample size and retrospective nature of this analysis are limitations. Being a single-centre experience, caution must be exercised in generalising these results. Authors were unblinded to the period of the case notes they were reviewing. Despite the use of a pre-defined complications checklist for all patients, this may be a small source of bias in support of ASU.

Conclusions

Introduction of the ASU resulted in compelling improvements in rates of definitive surgery on index admission and complications. In an era of challenging healthcare economics, the reduced length of stay and rate of representation are additional important advantages. This study extends the evidence base in support of this model of care. We recommend ASU as a framework which offers significant benefits for surgical patients and hospital systems.

CONFLICT OF INTEREST STATEMENT

Conflicts of interest; none. Ned Kinnear received a University of Adelaide Divisional Scholarship in relation to this work.

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Table 1: Demographics and outcomes of patients admitted with acute cholecystitis during the traditional and ASU periods.

	Trad period (n=172)	ASU period (n=148)	P value
Demographics			
Female	112 (65.1%)	93 (62.8%)	0.67
Median age (IQR) (years)	48 (33 – 62)	44 (34 – 54)	0.06
Primary outcomes			
Median length of stay (IQR) (days)	3.80 (2.69 – 6.61)	2.83 (2.04 – 4.16)	<0.0001
Definitive surgery on index admission	122 (70.9%)	141 (95.3%)	<0.0001
Median time to definitive surgery (IQR) (hrs)	28.1 (20.8 – 234.7)	22.1 (15.4 – 38.7)	<0.0001
Cases performed in-hours [a]	107 (87.7%)	131 (92.9%)	0.08
Secondary outcomes			
Median time ED referral to admission (IQR) (hrs)	5.19 (2.70 – 7.70)	4.50 (3.05 – 6.30)	0.13
Median time RCD to theatre start (IQR) (hrs) [a]	23.3 (18.3 – 35.4)	21.6 (15.3 – 28.7)	0.16
Conversion to open procedure [a]	22 (18.0%)	10 (7.1%)	0.007
Complications	42 (24.4%)	9 (6.1%)	<0.0001
Representation while awaiting elective LC [b]	17/50 (34.0%)	1/7 (14.3%)	0.29

a: data for cases receiving definitive surgery on index admission. **ASU**: Acute Surgical Unit. ***b***: Representation with biliary colic, cholecystitis, choledocholithiasis or gallstone pancreatitis. **ED**: emergency department. **hrs**: hours. **IQR**: interquartile range. **LC**: laparoscopic cholecystectomy. **n**: number of cases. **RCD**: radiologically confirmed diagnosis. **Trad**: traditional.

Table 2: Complications of patients admitted with acute cholecystitis during the traditional and ASU periods.

	Traditional period (n=172)	**ASU period (n=148)**
Total	**42 (24.4%)**	**9 (6.1%)**
Clavien-Dindo grade II		
Wound infection	3	1
Respiratory or urinary infection	9	3
Anaesthetic and medication complications	8	0
Gallstone pancreatitis	2	0
Cholecystectomy syndrome	5	1
Clavien-Dindo grade III		
Bile leak	6	2
Peri-cholecystic collection	6	1
Symptomatic choledocholithiasis	2	0
Incisional hernia	1	0
Urinary retention	0	1
Clavien-Dindo grade IV		
Confirmed bile duct injury	0	0
Clavien-Dindo grade V		
In-hospital mortality	0	0

ASU: acute surgical unit.

Chapter 5: Publication 4

Patient Satisfaction in Emergency General Surgery: A Prospective Cross-Sectional Study.

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Overall percentage (%)	50%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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ABSTRACT

Background: The importance of the patient experience is increasingly being recognised. However, there is a dearth of studies regarding factors affecting patient reported outcomes in emergency general surgery (EGS), including none from the Southern Hemisphere. We aim to prospectively assess factors associated with patient satisfaction in this setting.

Methods: In this prospective cross-sectional study, all consecutive adult patients admitted to an acute surgical unit over four weeks were invited to complete a validated Patient Reported Experience Measures questionnaire. These were completed either in-person when discharge was imminent or by telephone <4 weeks post-discharge. Responses were used to determine factors associated with overall patient satisfaction.

Results: From 146 eligible patients, 100 (68%) completed the questionnaire, with a mean overall satisfaction score of 8.3/10. On multi-variate analyses, eight factors were significantly associated with increased overall satisfaction. Five of these were similar to those previously prescribed by other like studies, being patient age >50 years, sufficient analgesia, satisfaction with the level of senior medical staff, important questions answered by nurses and confidence in decisions made about treatment. Three identified factors were new; sufficient privacy in the emergency department, sufficient notice prior to discharge and feeling well looked after in hospital.

Conclusions: Factors associated with patient satisfaction were identified at multiple points of the patient journey. While some of these have been reported in similar studies, most differed. Hospitals should assess factors valued by their EGS population prior to implementing initiatives to improve patient satisfaction.

Keywords: acute surgical unit; acute care surgery; emergency general surgery; satisfaction; experience; patient-reported outcomes.

1. INTRODUCTION

The expanding body of research into patient-reported experience/ outcome measures (PREMs/ PROMs) have generated questionnaires and insights for general practice, mental health, general medicine adult inpatients, obstetric services and paediatrics, as well as most medical sub-specialties (290-293). However, very little assessment has occurred of patient-reported outcomes in emergency general surgery (EGS). This is likely due to its unique challenges to planned patient questionnaire delivery. All presentations are unplanned and frequently occur after-hours. Admission numbers fluctuate widely from week to week, while patients are commonly in pain, nauseated or delirious, and move frequently between hospital locations and teams. Their heterogenous pathologies and requirements for investigations as well as variable access to operating theatres create unpredictable absences from the ward where questionnaires may be administered. The absence of Australian data on patient-reported outcomes in emergency general surgery was recently highlighted (42).

Models of care in EGS have undergone a significant transformation in the past two decades following the widespread adoption of the Acute Surgical Unit (ASU) structure. Compared with traditional arrangements, the ASU model allocates a consultant surgeon to the care of EGS patients, with few or no elective responsibilities. Amongst the wealth of studies assessing these models of care, most have collected only objective data, such as complications, length of stay and mortality (51, 58, 153, 163). However, there is growing recognition of the central importance of the subjective patient experience. Staff may be oblivious to much of the patient experience during and following admission, failing to recognise that patients are best placed to report their symptoms, satisfaction and how adequately care met their needs (290).

A small number of ASU studies have reported subjective outcomes, including the satisfaction of surgeons (294), trainees (295), emergency physicians (180) or even doctors' approximations of patient satisfaction, estimated without patient input (161, 180). None of these ASU studies have measured patient-reported outcomes. More broadly within an EGS population regardless of model, to date only three studies have explored the effect on patient reported outcomes of individual aspects of their inpatient experience (290, 296, 297). Collectively, their findings emphasised the importance patients place on effective staff communication, including staff listening and adequate explanations, as well as pro-active attempts to minimise noise and pain. All such studies have occurred in Europe or North American, and the factors valued by EGS patients in the Southern Hemisphere have not been assessed. This study therefore aims to assess patient reported satisfaction in an Australian ASU model and identify factors associated with higher patient satisfaction. These data may establish baseline values and identify areas for future improvement.

2. METHODS

Eligible patients were consecutive adults admitted to the ASU of our tertiary referral centre during the prospectively selected period 12/06 – 11/07/2019 inclusive. Patients were invited to complete a validated questionnaire. They were approached either in person in daytime hours 0800 – 1700 whilst an inpatient when discharge was anticipated to occur within 36 hours, or post-discharge by telephone within four weeks of admission. For telephone questionnaire delivery, at least three attempts were made to contact each patient. Patients were excluded if they declined involvement, were clinically unstable, lacked cognitive capacity or were incarcerated. Data on demographics and procedures performed were collected from electronic medical records for all eligible patients. For enrolled patients, questionnaire responses were recorded, in addition to time-to-theatre and complications.

Questionnaires were administered by research staff uninvolved in patient care. Patients were informed of this role separation, and that study involvement was voluntary, confidential, would not impact their treatment nor be entered in their medical record. No inducements to participate were offered. The primary outcome was the identification of items during the admission which were associated with patient satisfaction on multivariate analysis. There were no secondary outcomes. Study approval was granted by the Central Adelaide Local Health Network human research ethics committee (R20190323).

The General Inpatient Survey is a validated questionnaire used in the United Kingdom's National Health Service (NHS) for elective and emergency presentations. This study employed an abbreviated version of this instrument, that has been previously used to assess PROMs in EGS patients (290). Utilising this questionnaire, participants were asked whether during their admission they experienced each of 46 items 'at all times', 'sometimes' or 'not at all'. Care was taken to avoid confusion when the item was a positive or negative experience, such that 'at all times' was consistently understood to be the most positive option. Finally in question 47, participants rated overall satisfaction with their admission on a categorical scale from 0 to 10, representing worst and best possible satisfaction, respectively.

2.1. Data analysis

Responses were dichotomised using a previously validated 'top-box' approach (290, 296). For each questionnaire item 1 to 46, patients who responded 'at all times' were grouped and their mean overall satisfaction was calculated from question 47. Using the Mann Whitney U test, this was compared with the mean overall satisfaction of patients who responded 'sometimes' or 'not at all' to that same item. To adjust for multiple comparisons, the correction described by Hommel was used (298).

Multivariate linear regression analysis was then performed to identify items which remained significantly associated with satisfaction. Items significant in the univariate analysis (except those with missing data) were included in the model, with the addition of age, gender, whether or not an operation occurred, and the time-to-theatre. A forwards and backwards stepwise approach employing the Akaike information criterion was used to select items for final multivariate model. Diagnostic plots were used to assess heteroscedasticity, normality, and influential observations. Multivariate analyses were presented as β-estimates. A β-estimate of 1.2, for example, should be interpreted as a positive 'top-box' response ('at all times') to that particular question being associated with a raw 1.2 increase in overall satisfaction on a zero to ten scale, after adjusting for available variables.

Time-to-theatre was measured as time from emergency department presentation to operation start time. Data were presented as means unless otherwise stated. Categorical measures were summarised as proportions and assessed with Pearson's chi-square test. All tests were two-tailed and significance was assessed at the 5% alpha level. Missing data was reported if present. The analysis was conducted in R (299).

3. RESULTS

Within the four-week study period, 146 consecutive adult patients were admitted to the ASU and invited to participate. One hundred (68%) were enrolled, with 45 (31%) uncontactable and one (1%) declining. Compared to eligible patients unable to be enrolled, the 100 consenting eligible patients had similar median age (49 versus [vs.] 56 years, p=0.19) and proportion undergoing procedures (52% vs. 46%, p=0.49), although fewer were female (72% vs. 48%, p=0.007). Amongst the 100 participants, mean age was 54.0 years (standard deviation [SD] ±20.7, range 18-93) and mean time-to-theatre was 1.23 days (SD±1.04, range 0.14-5.56). All 100 consenting individuals were able to adequately complete the questionnaire, either in-person (three patients) or via telephone (97 patients).

3.1. Objective outcomes

Participants reported mean overall satisfaction score of 8.3. Objective factors not associated with satisfaction included gender (p=0.56), receiving a procedure (p=0.78) and time-to-theatre of <24 hours (p=0.66). However, compared with those aged <50 years, patients aged >50 years reported higher satisfaction scores (p=0.002). The association between satisfaction and complications was unable to be assessed, as Clavien-Dindo complications of grade III-IV occurred in only three patients. There were no deaths.

3.2. Univariate analysis

After adjustment for multiple testing, 30 items were significantly associated with patient satisfaction on univariate analysis. Significant items in the questionnaire related to all aspects of the patient journey, including admission, ward environment, patient-staff interactions, information and involvement in treatment, discharge, and the overall experience (Table 1).

3.3. Multivariate analysis

In addition to patient age >50 years, the following seven items were significantly associated on multivariate analysis with increased overall satisfaction: reporting sufficient privacy in the emergency department, satisfaction with the level of senior medical staff, sufficient pain control by staff, important questions answered by nurses, confidence in decisions made about treatment, sufficient notice prior to discharge and feeling well looked after in hospital (all $p<0.05$) (Table 1).

4. DISCUSSION

On multivariate analysis, eight factors were found to be significantly associated with patient satisfaction. One of these were less informative, specifically 'feeling well-looked after in hospital,' being a paraphrasing of overall satisfaction with the admission. Additionally, while patient age cannot be modified, the association between age >50years and greater satisfaction is interesting and may suggest this demographic holds greater tolerance of inconvenience and information scarcity, or more benevolent attitudes towards clinicians. The other six identified items offer opportunities for quality improvement widely within the hospital, including the emergency department, nurses and junior and senior surgical staff.

The emergency department is for most patients their first hospital location during an unplanned and potentially uncomfortable admission. These results highlight the importance of efforts to maintain patient privacy and dignity in this area, such as closing cubicle doors and curtains during consultations and especially examinations. As care continues in a ward environment, patients must be kept well informed, regarding both treatments and likely discharge timing. While this is often the remit of junior doctors, these findings reaffirm the value patients place on communication from both nurses and senior medical staff. Lastly, every effort should be made by all staff to provide appropriate analgesia.

To date, ten studies have assessed patient-reported outcomes in emergency general surgery (Table 2) (57, 158, 290, 296, 297, 300-304). However, only three have performed multivariate analysis or attempted to isolate factors associated with increased satisfaction (290, 296, 297). All three utilised the same 'top-box' statistical methodology of this study. Of the factors identified by this study, five overlapped with these previous studies. These were greater patient age, confidence in nurses, sufficient explanations, input from senior surgeons and adequate pain-relief (290, 296, 297). Three factors identified herein were novel, namely sufficient privacy in the emergency department, sufficient notice prior to discharge and feeling well looked after in hospital. Contrastingly, the prior similar studies reported several additional items not detected in our study. Jones *et al*., who similarly utilised the NHS' General Inpatient Survey, found the absence of night-time noise to be positively correlated with satisfaction at their Edinburgh centre (290). Studies applying different questionnaires also noted patient satisfaction to be associated with nurses and doctors listening, respect from doctors and shared decision making, and inversely correlated with patient level of education (296, 297).

Of the three like studies, only Kahn *et al*. described intended or actual practice change based on their findings to improve the quality of future patient care (297). Within their hospital in New York, the authors personally further encouraged patients to pro-actively ask for analgesia, organised staff in-service education on noise minimisation and discharge planning and delivered hospital-wide seminars on listening skills. No plan to measure the impact of these measures was described. In our institution, we intend to utilise this study's findings to guide quality improvement activities, and then re-audit to determine the impact on patient satisfaction. Planned actions included feedback to emergency department staff on the importance of closing cubicle dividers during examinations, and nursing and medical staff meetings to re-enforce both encouraging patients to ask for analgesia and conducting discharge planning discussions early in the admission. We also intend to present these findings, along with recommended clinician behavioural change, at our institution's educational 'grand round' assembly.

Internationally, the systematic collection of PROMs is becoming embedded in routine care (305-307). The resulting wealth of information has led to a broad spectrum of applications (308). For individual patients, PROMs have been applied to detect symptoms and assess treatment impact. Within hospitals, PROMs have seen extensive uptake in quality improvement initiatives and assessing the comparative effectiveness of treatments (309). At a population level, PROMs are increasingly being used to allocate healthcare funding to maximise patient value, including in the

United States of America (USA) (310) and United Kingdom (308, 311). Subsequently, nationally embedded use of PROMs has been recommended by Great Britain's National Health Service (NHS) (305), much of Europe (306) and the USA's Food and Drug Administration (307). The Australian Commission on Safety and Quality in Health Care are currently scoping means to adopt these practices, in keeping with the recognition of consumer-centred care as the first of three pillars of safe and high-quality care (308, 312). This study represents the first local attempt to fulfil this goal in EGS. The response rate was 68%, which compares favourably with other similar studies (Table 2).

Key choices for systematic assessment of PROMs amongst surgical patients are questionnaire administration either as inpatient or post-discharge, and by paper, telephone, hospital electronics or patient electronics. Inpatient paper-based methods appear feasible, given the low cost and existing paper-based collection of other patient data, such as procedural consent and meal preferences. Interest is expanding in inpatient delivery via hospital electronic systems, and has included tablet computers and web kiosks (313). Post-discharge mailed questionnaires are routine in many elective settings, being mandatory in the United Kingdom's National Health Service following hip or knee replacement, inguinal hernia repair or varicose vein surgery (308, 314). Internet delivery has been utilised in many countries to perform large scale post-discharge PROMs collection via patient electronics, such as the National Institute of Health's PROMIS instrument in the USA (315). Lastly, social media and automated telephone survey systems have also been successfully employed post-discharge (316, 317). Before choosing from the above methods, health networks should consider their suitability to the target population. Simpler technology, such as paper- or telephone-based options, are familiar to a broader range of patients and accrue lower start-up costs, but require costly subsequent translation of responses into databases and may suffer lower participation rates. Electronic methods allow easy scalability, immediate database entry and appeal to younger patients. However, they have documented issues including cost of development and variable patient access to internet and technology familiarity, particularly for older persons or ethnic minorities (308).

Key areas for future research are prospective demonstrations that interventions aimed at addressing EGS patient satisfaction actually improve outcomes, be they future patient satisfaction, cost or clinical metrics such as length of stay and complications. Further studies are also needed to re-confirm these findings in the Australasian setting and assess the psychometric validity of the NHS' General Inpatient Survey, which has not yet occurred.

This study is limited by its small sample size and single-centre design, which may affect its generalisability. The resource-intense methodology of administering questionnaires in person or via telephone would limit scalability to large cohorts. Additionally, there is the potential for recall bias, as the majority of patient questionnaires were delivered by telephone <4 weeks post-discharge. The reporting bias associated with clinicians recruiting and collecting the data from patients could not be quantified.

4.1. Conclusion

Factors associated with satisfaction were identified from all areas of the patient journey. While some overlap occurred with factors observed in other similar studies, many differed. Hospitals should therefore assess factors valued by their EGS patient population before implementing initiatives to improve patient satisfaction.

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TABLES

Table 1. Relationship between mean patient satisfaction and experience items.

	Univariable analysis				Multi-variable analysis §		
	At all times	Sometimes or never	Miss.	*p* value †	β	CI	*p* value
Admission							
1. Sufficient information in ED	8.67	7.32	-	0.006	||		
2. Sufficient privacy in the ED	8.49	7.07	-	0.012	0.80	0.20-1.40	0.01 *
3. Did not experience a long wait for bed in ward	8.45	7.97	-	0.28			
Ward Environment							
4. No night-time noise from other patients	8.44	7.89	-	0.16			
5. No night-time noise from staff	8.41	8.00	-	0.8			
6. High levels of ward cleanliness	8.35	7.43	-	0.64			
7. No threatening behaviour from other patients or visitors	8.80	8.23	-	0.37			
8. High satisfaction with the food	8.67	7.90	-	0.021	-0.29	-0.71-0.13	0.17
9. Sufficient help at mealtimes	8.37	6.80	-	0.75			
10. Enough nurses on the ward	8.42	7.10	-	0.003	||		
11. Sufficient privacy for clinical discussions	8.45	6.14	-	0.01	0.77	-0.10-1.64	0.08
12. Sufficient privacy for examination and treatment	8.47	6.25	-	0.006	||		
Patient-staff interaction							
13. Confidence and trust in doctors responsible for care	8.59	7.00	-	0.0004	||		
14. Satisfaction with level of seniority of medical staff	8.53	6.79	-	0.0009	0.89	0.31-1.46	0.003 *
15. Did not experience doctors talking in front of patients as if not present	8.42	7.81	-	0.3			
16. Confidence and trust in nurses	8.56	6.09	-	0.0006	||		
17. Did not experience nurses talking in front of patients as if not present	8.39	7.58	-	0.62			
18. Staff to talk to about worries and fears	8.59	6.82	-	0.008	||		
19. Sufficient emotional support from staff	8.65	6.67	-	<0.001	||		
20. No pain	8.63	8.18	-	0.13			
21. Sufficient pain control from staff	8.57	6.25	-	<0.001	1.30	0.64-1.97	<0.001 *
Information and involvement in treatment							
22. Important questions answered by doctors	8.73	6.42	-	<0.001	||		
23. Important questions answered by nurses	8.59	6.82	-	<0.001	0.79	0.25-1.33	0.005 *
24. Involvement in decisions about treatment	8.62	7.17	-	<0.001	||		
25. Confidence in decisions made about treatment	8.72	6.33	-	<0.001	0.63	0.00-1.26	0.048 *
26. Sufficient information given about treatment	8.74	6.50	-	<0.001	||		
27. Sufficient explanation of risks and benefits of surgery	8.65	6.50	3	0.004	||		
28. Sufficient explanation of operation details	8.65	6.50	3	0.09			
29. Questions answered about surgery	8.65	7.22	3	0.003	||		
30. Sufficient pre-op explanation of what to expect post-op	8.76	7.50	3	0.001	||		
31. Sufficient explanation from anaesthetists	8.47	7.40	3	0.32			
32. Sufficient post-op explanation of operation findings	8.84	7.08	3	0.008	||		
Discharge Process							
33. Involvement in discharge decision-making	8.68	7.53	-	0.01	||		
34. Sufficient notice prior to discharge	8.70	6.65	-	<0.001	0.62	0.07-1.17	0.028 *
35. Discharge not delayed	8.49	7.68	-	0.093			
36. Provision of written information	8.70	7.19	-	<0.001	||		
37. Explanation of purpose of discharge medication	8.72	6.20	52 ‡	0.30			
38. Explanation how to take discharge medication	8.79	5.80	53 ‡	0.04	||		
39. Warning of danger signals to look out for at home	8.84	7.74	-	0.002	0.29	-0.12-0.70	0.17
40. Consideration of family situation in planning discharge	8.68	6.91	-	<0.001	||		
41. Sufficient information given to family	8.68	6.91	-	<0.001	||		
42. Information given for who to contact if concerned	8.66	7.68	-	0.07			
43. Discharged with required equipment/ home adaptations	8.88	8.10	66 ‡	0.25			
44. Discharged with all required community/ social care	9.00	8.30	62 ‡	0.53			
Overall Experience							
45. Treated with dignity	8.52	6.20	-	<0.001	||		
46. Felt well-looked after in hospital	8.67	5.50	-	<0.001	1.24	0.46-2.02	0.002 *

β: β-estimate. CI: 95% confidence interval. ED: emergency department. Miss.: missing. n.s.: not significant. †: with Hommel correction for multiple analyses. ‡: patients who did not require discharge medication, equipment or community services were advised to skip irrelevant questions. §: age adjusted. ||: As described in Methods, the Akaike information criterion was used to select items significant on univariable analysis that progressed to the final multivariable model. *: statistically significant on multivariable analysis.

Table 2. Studies of patient reported outcomes in emergency general surgery

Year	First author	Nation	EGS subset	Model	Site	Retro. / pro.	Period (days)	Eligible pts	Enrolled pts	Response rate (%)	Non-responders assessed?	Enrolled EGS pts (%)	EGS operations (%)	PROMs collection method	Treating team collected data	Top box method	Multi-variable analysis
Studies describing associations between individual factors and patient satisfaction																	
2015	Kahn (297)	USA	All EGS	ASU	Single	Retro	548	-	184	-	No	184 (100%)	109 (59%)	Mail	-	Yes	Yes
2015	Schmocker (296)	USA	EGS + elective †	-	Single	Pro	152	1007	435	43%	Yes	100 (23%)	100 (100%) †	Mail	-	Yes	Yes
2017	Jones (290)	UK	All EGS †	-	Single	Pro	28	87	68	78%	Yes	68 (100%)	68 (100%) †	In-person or phone	-	Yes	Yes
Other studies																	
2013	Forrestal (300)	Ireland	Daytime EGS	SAU vs. ED	Single	Pro	56	-	115	-	No	115 (100%)	-	In-person or phone	-	No	No
2014	Eijsvoogel (158)	Netherlands	All EGS	ASU	Single	Pro	61	249	99	40%	No	99 (100%)	-	-	-	N/a	N/a
2015	Ali (303)	Canada	All EGS	ASU	Single	Pro	365	238	116	49%	No	116 (100%)	-	In-person then mail	-	No	No
2015	Johnstone (57)	UK	All EGS	SAU vs. ED	Single	Pro	56	-	186	-	No	186 (100%)	-	In-person	-	No	No
2017	Navarro (302)	UK	All EGS	SAU vs. ED	Single	Both	152	1773	351	20%	No	351 (100%)	-	-	-	N/a	No
2018	Kwong (301)	UK	EGS laparotomies †	-	Multi	Pro	105	255	190	75%	Yes	190 (100%)	190 (100%) †	Mail	Yes	No	No
2019	Ullah (304)	Ireland	Daytime EGS	Old vs. new SAU	Single	Pro	243	-	200	-	No	200 (100%)	-	-	-	No	No

ASU: acute surgical unit. ED: emergency department. EGS: emergency general surgery. Phone: telephone. Pro.: prospective. PROMs: patient reported outcome measures. Pts: patients. Retro.: retrospective. SAU: surgical assessment unit. UK: United Kingdom. USA: United States of America. Vs.: versus. %: percentage. -: not stated. †: only patients undergoing a procedure were eligible.

Chapter 6: Publication 5

Emergency general surgery models in Australia: a cross-sectional study

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Overall percentage (%)	50%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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ABSTRACT

Objective: Emergency general surgery (EGS) patients experience superior outcomes when cared for within an acute surgical unit (ASU) model. EGS structures in most Australian hospitals remain unknown. This study aimed to describe the national spectrum of EGS models.

Methods: A cross-sectional study was performed of all Australian public hospitals of medium or greater peer group (>2000 patient separations per annum). The primary outcome was the incidence of each EGS model. Secondary outcomes were the relationship of the EGS model to objective hospital variables, and qualitative reasons for the choice of model.

Results: Of the 120 eligible hospitals, 119 (99%) participated. Sixty-four hospitals reported using an ASU (28%) or hybrid EGS model (26%), whereas the remaining 55 (46%) used a traditional model. ASU implementation was significantly more common among hospitals of greater peer group, bed number, surgeon pool and trauma service sophistication. Leading drivers for ASU commencement were aims to improve patient care and decrease after-hours operating, whereas common barriers against uptake were insufficient EGS patient load or surgeon on-call pool.

Conclusions: ASU or hybrid models of care may be more widespread than currently reported. The introduction of such structures is heavily dependent on hospital and staff size, trauma subspecialisation and EGS patient throughput.

Keywords: acute care surgery, acute general surgery, acute surgical unit.

INTRODUCTION

Emergency patients comprise the majority of workload and deaths within general surgical departments (49). In the United States of America (USA), emergency general surgical patients annually comprise >3 million admissions at a cost of more than US$28 billion (318, 319). The number of emergency general surgery (EGS) patients is also rising relentlessly, by >30% each decade in Europe and the USA (3, 72). However, despite representing the majority of general surgical workload, EGS patients rarely feature in hospital key performance indicators (52). Traditional structures have long been aligned with providing optimum care for elective patients, often at the expense of EGS patients. Surgeons and trainees were typically rostered for elective operating and clinics, with EGS patients managed ad hoc, either by delay or cancellation of elective patients, or after hours.

In 1996, a new model was trialled with the separation of elective and emergency general surgical activity (3). This model would come to be best known as the acute surgical unit (ASU), and its positive results led to uptake across Europe, the US and Australasia (51, 212). The model's central component is a surgeon, on-site in business hours and on-call after hours, dedicated to EGS patients without elective or private commitments during their shift. Additional features may include an EGS-allocated trainee and protected theatre access.

To date, sixteen Australian public hospitals have published their uptake of the model, whereas another two have documented successful persistence with traditional or subspeciality models (see Appendix 3). However, for the great majority of public hospitals in Australia, the model in use remains unknown. In 2010, General Surgeons

Australia's (GSA) 12 Point Plan for Emergency General Surgery recommended separation of emergency and elective activity (66). However, these were non-binding recommendations and explicitly expected variation in EGS models. Departments remain free to choose their preferred system, and no national registry or automated reporting of structure exists. This lack of information regarding EGS models in the large majority of Australian hospitals is problematic. A comprehensive national cross-sectional study could be used to guide other hospitals considering commencing an ASU, or by health bodies to inform future policy.

Therefore, this study aimed to assess the structure of EGS care of adults in all Australian medium to major public hospitals, with particular regard to the chronological and geographical spread of EGS models, the association with sophistication of local trauma care and other variables on choice of EGS model and reasons for or against commencing an ASU model. We hypothesised that most medium- to major-sized Australian hospitals would use an ASU or hybrid model.

METHODS

In the present cross-sectional study, Australian public hospitals offering elective general surgery were identified from the Australian Institute of Health and Welfare's (AIHW) data, published December 2018 (320). Small, children's, unpeered hospitals or private hospitals were excluded (for definitions, see Appendix 4).

After inter-researcher verbal rehearsal for standardisation, all medium- to major-sized Australian hospitals were contacted by telephone during March–April 2019. At each hospital, the on-call general surgery registrar and the head of general surgery (or available senior surgeon) were each invited to participate. Eligible registrars were any doctors responsible for EGS referrals on the day the authors contacted their hospital who had at least one tier of EGS on-call supervision above them, regardless of whether they were in accredited training programs or referred to as 'registrars' in their hospital. At least three attempts were made to contact each participant. Before delivery of the questionnaire, the voluntary and confidential nature of the study was clearly explained and verbal consent to participate was obtained. A predefined questionnaire (see Appendix 5) was administered, with responses recorded in writing. No audio was recorded and incentives for participation were not used.

Primary outcomes were the proportion of hospitals using each EGS model and the chronological and geographic spread of the ASU or hybrid model. Secondary outcomes were the relationship of the EGS model to trauma surgery care and other variables, reasons for and against model implementation and hospital-reported cost analyses.

Each hospital's structure of EGS delivery was categorised as ASU, hybrid or traditional. An ASU model was defined as one in which the on-call general surgeon was allocated to EGS patients for ≥50% of business hours. A hybrid model did not allocate a dedicated on-call surgeon, but did have either a doctor-in-training rostered solely to EGS patients for ≥50% of business hours or two or more protected theatre half-day lists per week for EGS patients. Traditional units had none of these features. Other structural features, such as dedicated EGS beds or handover routines, were noted but did not affect the assigned EGS model. Trauma care categories were defined as Level 1 trauma centre, non-Level 1 hospitals still accepting major trauma or on bypass for major trauma.

To most accurately characterise a department's model, at each hospital both the on-call general surgery registrar and senior surgeon were asked to describe the elective commitments of both registrar and surgeon while on call, as well as the existence of protected EGS theatre access. In cases of conflicting data, the surgeon's response was taken as correct, except regarding registrar commitments, where the registrar's lived experience was prioritised. When graphing the number of ASU or hybrid units over time, a simple sigmoid growth curve was created between the known start (no such Australian model before 2005 (197)) and end (total such units at the time of the study) points. Ethics approval was granted by the Central Adelaide Local Health Network Human Research Ethics Committee (R20180812).

Statistical analysis

Categorical measures are summarised as proportions and were assessed with Pearson's Chi-squared test. All tests were two-tailed and significance was assessed at the 5% α level. Missing data were reported if present.

RESULTS

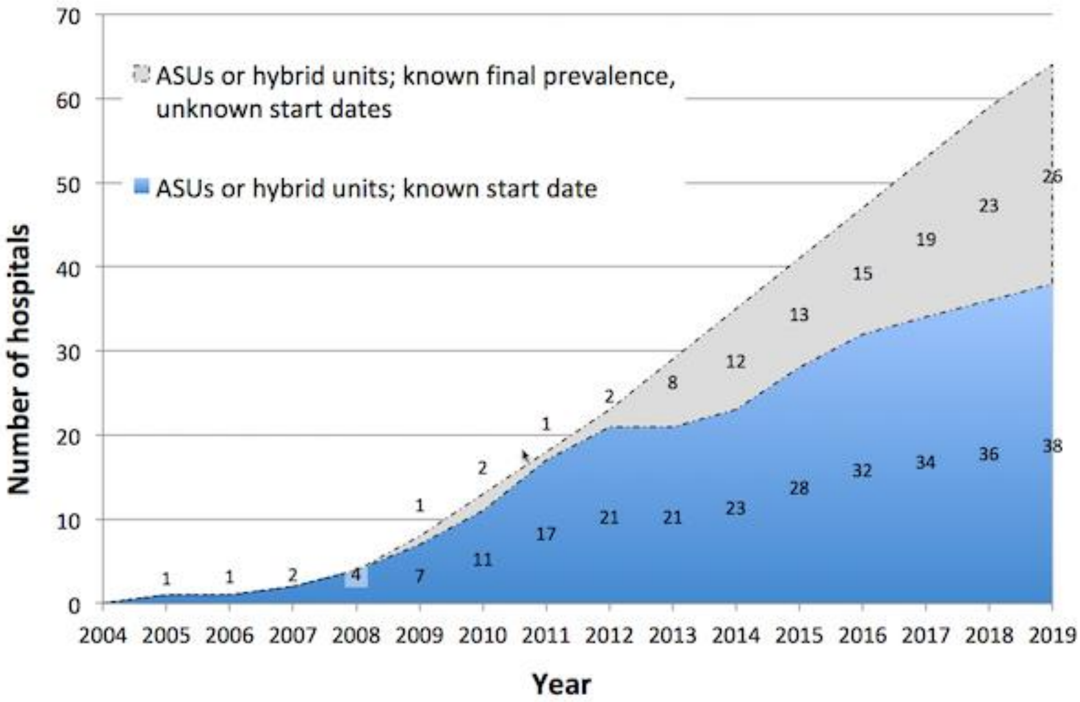
Primary outcomes

In total, 243 public hospitals were found to offer elective general surgery in Australia. After excluding 109 small, children's or unpeered sites, the remaining 134 medium- to major-sized hospitals were contacted. Respondents identified one additional site introduced subsequent to the publication of the AIHW's list, resulting in 135 hospitals (Appendix 6). Fifteen reported neither admitting nor operating on emergency patients, and were excluded from further analysis, resulting in 120 total eligible hospitals. From these, the questionnaire was completed by at least one staff member at 119 (99%) sites, including 107 of 120 surgeons (89%) and 115 of 116 registrars (99%), with four sites not involving registrars in EGS on-call (Table 1).

The implementation of ASU or hybrid units was observed to grow steadily from 2005 to the present, with an ASU or hybrid model now present in all states and territories, and the majority of medium to major Australian public hospitals (Figure 1, Figure 2). Thirty-three hospitals (28%) used an ASU model, whereas a further 31 (26%) chose a hybrid model. The remaining 55 hospitals (46%) used a traditional model. This included four hospitals with a subspeciality model, whereby all general surgical subspeciality teams are on call Monday–Friday (and, in some cases, on the weekend) for patients with relevant diagnoses.

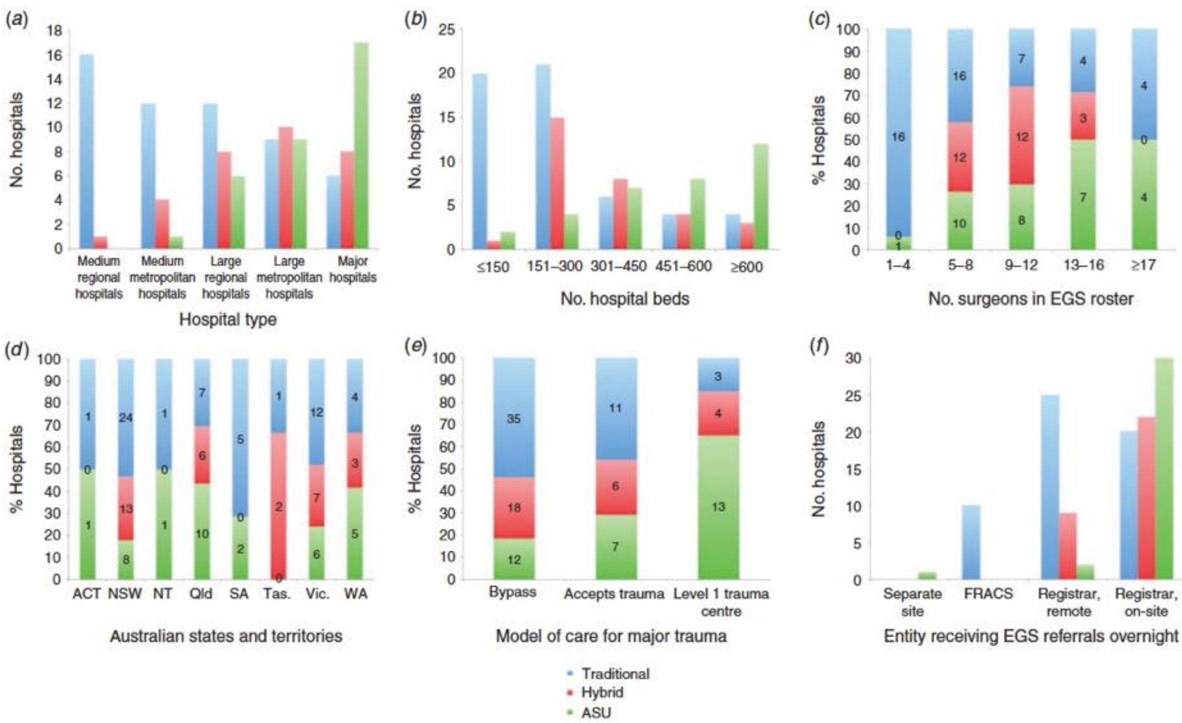
Of enrolled hospitals, 113 of 119 (95%) reported the presence or not of handover practices when the surgeon on-call changed. Twenty-seven hospitals described established departmental rules for handover at these times. In all cases, these rules were for patients still requiring an operation, with ongoing diagnostic ambiguity and/or remaining admitted after a prespecified duration. Such rules were significantly more likely to occur within an ASU, being present in 15 of 33 such units (45%), compared with eight of 31 hybrid models (26%) and four of 49 traditional models (8%; $P = 0.0005$).

Figure 1. Number of acute surgical unit or hybrid emergency general surgery models in Australia.



ASU: acute surgical unit.

Figure 2. Distribution of emergency general surgery models by (A) hospital peer group, (B) hospital bed size, (C) number of surgeons in on-call pool, (D) Australian state or territory, (E) major trauma model and (F) entity receiving referrals overnight.



ASU: acute surgical unit. EGS: emergency general surgery. FRACS: Fellow of the Royal Australasian College of Surgeons. Trad: traditional.

NB. Data was available for 119/119 (100%) hospitals for all graphs except Figures 2.c. and 2.e., for which data was available for only 104/119 (87%) and 109/119 (92%) sites, respectively.

Secondary outcomes

ASU models were significantly more common in hospitals of greater peer group ($P < 0.0001$), greater bed number ($P < 0.0001$) or with more surgeons in the EGS on-call pool ($P = 0.0003$; Figure 2). Of 33 hospitals using an ASU model, none were in medium-sized regional hospitals, only two were in hospitals of ≤150 beds and just one in a hospital with four or fewer surgeons in the EGS on-call roster. The EGS model was not related to Australian state or territory ($P = 0.42$).

Trauma care model was determined for 109 of 119 sites (92%), with ASU models significantly more common among hospitals provisioning more advanced trauma care ($P = 0.002$). Data on the presence of dedicated trauma surgeons was available for 106 of 119 sites (89%). Only seven sites reported having a dedicated trauma surgeon on staff. These were all within recognised Level 1 trauma centres, in hospitals with either ASU (six sites) or hybrid (one site) models of EGS care.

Drivers for change

Senior surgeons at 34 of 64 sites (53%) with an ASU or hybrid EGS model described their hospital's reasons for change from the traditional model. Multiple causes were permitted per site. In all, 74 responses fitting 15 categories were received (Appendix 7). The leading reported drivers for change were the desire to improve care for EGS patients (12 hospitals), reduce after-hours operating (11 hospitals) and address rising EGS patient load (9 hospitals). Notably, surgeons also reported ASU implementation in response to publicised benefits or governmental or speciality-group reports. These included convincing results from the Prince of Wales Hospital (NSW, Australia) or Fremantle Hospital (WA, Australia), influential presentations by past presidents of the Royal Australasian College of Surgeons (RACS), GSA's aforementioned policy (66) and the Honourable Peter Garling's commissioned inquiry into acute care services in New South Wales (98).

Barriers to change

Conversely, 56 of 86 hospitals (65%) using traditional or hybrid EGS models reported considering changing further towards an ASU structure, but not doing so due to perceived barriers. Multiple causes were permitted per site, with 68 responses fitting nine categories received (Appendix 7). The leading reported barriers to instituting an ASU were insufficient EGS patient load (33 hospitals), insufficient surgeons to allocate one solely to EGS (11 hospitals) and insufficient funding (9 hospitals). Three hospitals reported unsuccessful formal attempts to commence an ASU, all frustrated by insufficient funding. These occurred in one each of a large regional, medium metropolitan and large metropolitan hospital.

ASU units of the past or future

Included in the above 56 hospitals, 12 sites (six with a traditional model and six with a hybrid model) reported planning to start an ASU in the future. Motivations were similar to the drivers for change described above. Separately, five hospitals reported trialling an ASU model but experiencing challenges and reverting to a traditional (one site) or hybrid (four sites) model. These are summarised in Appendix 8. Reported reasons for reversion formed common themes of insufficient EGS load, insufficient staff surgeons and surgeon fatigue.

Cost analyses

Three of the 33 hospitals using an ASU reported assessing the financial impact of its introduction. Savings occurred in one major hospital and one large regional hospital, with the latter publishing their costings (162), whereas another large regional hospital experienced cost neutrality. Only one of 31 hospitals with a hybrid structure described financial assessment of the change in EGS structure. This major hospital observed that staffing in the new model required increased expenditure.

DISCUSSION

The results of the present study suggest significant change during the past two decades in EGS care in Australia. This change began with the establishment of the nation's first ASU in 2005 (197) and leads to present day, with the majority of medium to major public hospitals now using an ASU or hybrid model. Although the present study's generalisability is limited by its assessment of only Australian centres, the identified leading motivators for EGS model change are common globally, namely improving patient care, reducing after-hours operating and expedited patient throughput (60).

Several previous studies have attempted to establish the spectrum of EGS models. Via unspecified correspondence methods, Uranues and Lamont contacted 51 EGS 'experts' in 27 European countries (321). Among 18 responding countries, three

(17%) were found to use an ASU model. However, as demonstrated by the present study and by others (322), significant variation in EGS models exists within the same state or country, and thus these results are only a guide to European practices. State-based assessments of hospitals in Canada, the US and UK have reported ASU uptake rates of 8–29% (322-324). At the national level, a postal and email assessment of all American hospitals containing both an emergency department and operating theatre reached 1690 of 2811 hospitals (60%), with 16% using an ASU model (318). Similarly, a UK online questionnaire enrolled one or more colorectal surgeons from 104 of 135 acute non-specialist National Health Service Trusts (77%) and reported ASU uptake in 26% of hospitals (325). Together, these findings indicate ASU implementation rates in developed nations range from 8% to 29%, similar to the findings of the present study. Compared with other studies, the present study enjoyed an excellent response rate of 99%. Furthermore, although most studies dichotomously categorised EGS structure to traditional or ASU, the present analysis allowed for real-world variety by including hybrid structures. In addition, the present study's approach of categorising EGS structure based on staff rostering and theatre allocation, rather than hospital self-description, avoids confounding by the acknowledged practice whereby surgical departments rebrand without substantially modifying services (326).

There has been limited interest in the past 5 years in an alternative EGS model: the surgical assessment unit (327). None have been reported in Australia. Surgical assessment units base an EGS-dedicated surgeon in the emergency department, to whom patients with probable EGS diagnoses are referred by the emergency department triage nurse (or, in some countries, general practitioners). Patients bypass assessment by emergency department physicians. This structure may offer similar benefits to the ASU, although results have been mixed. Two hospitals in the present study reported local interest in, but not yet commencement of, a surgical assessment unit. Both sites were stimulated by hospital renovations creating additional space in the emergency department.

Patient handover is a common cause of preventable injury in surgery, with emergency patients particularly at risk (328). Patient handover is infrequent within traditional structures, with patients typically cared for by a single surgeon throughout their admission. Through increased consultant involvement and reduced after-hours operating, the ASU model potentially improves patient safety. However, shift work systems disrupt continuity of care and potentially worsen safety. Reassuringly, however, the pooled effect of these factors appears positive, with all existing comparative ASU studies reporting equivalent or reduced complications (212). An Australian ASU study found that surgeon-to-surgeon handover did not affect patient outcomes (197), whereas in the UK, trainees who worked within an ASU reported greater satisfaction with handover practices (329). Similarly, the present study found that standardised patient handover was more likely to occur in ASU models. However, the existence of such rules in only 45% of ASUs was lower than expected, given the model's need for frequent handover. Structured handovers in general surgery are known to significantly increase the quality of information transfer (330). Hospital departments caring for EGS patients, particularly within an ASU model, should examine and define their handover protocols.

Limitations of this study include its reliance on descriptions from participating doctors, who may be under time pressure or new in their position. There were occasional instances where surgeons and registrars differed in describing their EGS model. Our resolution approach described in the Methods section may nevertheless have rarely misallocated EGS model.

Conclusion

ASU or hybrid models of care for EGS patients may be more widespread than currently reported. Introduction of such structures is heavily dependent on hospital and staff size and trauma subspecialisation. These findings may provide guidance for policy makers and hospitals considering implementing an ASU.

COMPETING INTERESTS

The authors report no competing interests.

ACKNOWLEDGEMENTS

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TABLES

Table 1. Cross-sectional study results by staff and service.

Staff or service	Number (%)		
Registrars			
Enrolled/ Declined/ Uncontactable	115/ 1/ 0 †		
Consultants			
Enrolled/ Declined/ Uncontactable	107/ 3/ 10		
EGS model			
Acute surgical unit *n* (%)	33	(28%)	
Hybrid *n* (%)	31	(26%)	
Traditional *n* (%)	55	(46%)	
Unknown *n* (%)	1	(1%)	
Services dedicated to EGS patients			
On-call surgeon *n* (%) ‡	33	(28%)	
On-call registrar *n* (%) ‡	49	(41%)	
Theatre *n* (%) §	82	(69%)	
Beds, any *n* (%)	15	(13%)	
Median (range) no. of EGS beds	12	(4 – 28)	
No. consultants in EGS on-call roster			
1 – 4 consultants: *n* sites with ASU / n sites total	1 /	17	(6%)
5 – 8 consultants: *n* sites with ASU / n sites total	10 /	38	(26%)
9 – 12 consultants: *n* sites with ASU / n sites total	8 /	27	(30%)
13 – 16 consultants: *n* sites with ASU / n sites total	7 /	14	(50%)
≥17 consultants: *n* sites with ASU / n sites total	4 /	8	(50%)

ASU: acute surgical unit. N: number. †: four sites reported not involving registrars in EGS on-call. ‡: allocated to EGS patients for ≥50% of business hours. §: ≥2 protected theatre lists per week for EGS patients. %: percentage. Denominators for all percentages are the 119 participating hospitals, unless otherwise specified.

LIST OF SUPPLEMENTARY MATERIAL

1. Australian hospitals that have published their emergency general surgery model.

2. Australian Institute of Health and Welfare hospital peer groups relevant to general surgery, abbreviated.

3. Telephone questionnaire template.

4. Australian medium to major public hospitals invited to participate in this study.

5. Reported reasons for and against change towards an Acute Surgical Unit model.

6. Case vignettes of hospitals which reverted to Traditional or Hybrid structures following trial of an Acute Surgical Unit model.

Supplementary material available in Appendices.

Chapter 7: Publication 6

Does emergency general surgery model affect staff satisfaction, training and working hours?

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Name of Principal Author (Candidate)	Ned Kinnear		
Contribution to the Paper	Submitted ethics application, collected data, performed data analysis, wrote manuscript first draft and acted as corresponding author.		
Overall percentage (%)	50%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/12/21

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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ABSTRACT

Background: Few studies have assessed the relationship between different Emergency General Surgery (EGS) models and staff satisfaction, operative experience or working hours. The Royal Australasian College of Surgeons recommends maximum on-call frequency of one-in-four for surgeons and registrars.

Methods: A cross-sectional study was conducted of all medium- to major-sized Australian public hospitals offering elective general surgery. At each site, an on-call general surgery registrar and senior surgeon were invited to participate. Primary outcomes were staff satisfaction and registrar-perceived operative exposure. Secondary outcomes were working hours.

Results: Amongst eligible hospitals, 119/120 (99%) were enrolled. Compared with Traditional EGS models, Hybrid or Acute Surgical Unit (ASU) models were associated with greater surgeon and registrar satisfaction on quantitative (p=0.012) and qualitative measures. Registrar-perceived operating exposure was unaffected by EGS model. Longest duration on-duty was higher amongst Traditional structures for both registrars (mean 22 vs. 15 hours; p=0.0003) and surgeons (mean 59 vs. 41 hours; p=0.020). On-call frequency greater than one-in-four was more common in Traditional structures for registrars (51% vs. 28%; p=0.012) but not surgeons (6% vs. 0%; p=0.089). Data on average hours per day off-duty were obtained for registrars only, and were lower in Traditional structures (13 vs. 15 hours; p=0.00002).

Conclusion: Hybrid or ASU models may improve staff satisfaction without sacrificing perceived operative exposure. While average maximum duration on-duty exceeded hazardous thresholds for surgeons regardless of model, unsafe working hours for registrars were more common in Traditional structures. General surgical departments should review on-call rostering to optimise staff and patient safety.

Keywords: acute surgical unit, acute general surgery, acute care surgery, emergency general surgery.

1. INTRODUCTION

Emergency General Surgery (EGS) patients exceed their elective counterparts in number of admissions, mortality and cost (49). Traditionally, general surgical departments rostered staff to elective operating and outpatient clinics, with EGS patients assessed and treated after hours, or at the interruption of elective duties. An appetite for improvement grew from dissatisfaction with these arrangements, combined with international factors. These included the United Kingdom government recommending consultant-led care (3), and in the United States of America (USA) an imperative to re-imagine the scope of trauma surgeons in the face of declining trauma workload and trainee applications (88, 179). A new Acute Surgical Unit (ASU) model was first established in Scotland in 1996 (3) and spread across Europe, the USA and Australasia (212). Emergency and elective work were separated, with rostering of a general surgeon dedicated solely to EGS patients. The model was refined to commonly involve a dedicated registrar and/ or operating theatre list allocated to EGS patients. Rapid uptake of these systems nationally and internationally is likely driven by the published benefits of the ASU model. Patients frequently experience decreased time to theatre, length of stay and complication rates (51, 58, 163). Cost savings via an ASU model have been reported in the United Kingdom (127), USA (331), Canada (161) and Australia (162).

However, the needs of surgeons and trainees have frequently been overlooked. These include safe working hours, work satisfaction and operative learning opportunities. In Australia, eighteen public hospitals have documented their EGS structures to date. However, staff satisfaction (155), on-call frequency (51, 157, 190) and trainee operating experience (121, 153, 166, 191, 194, 196) have been only rarely reported, and remain unknown for the remaining great majority of Australian hospitals. Furthermore, the Royal Australasian College of Surgeons recommends on-call ratios for surgeons and registrars be no more frequent than one-in-four (112). No national study has measured adherence to this policy or the safety of EGS staff hours.

We aimed to assess the relationship between EGS structure and work satisfaction, perceived operative exposure and working hours amongst general surgery staff in all medium- to major-sized Australian public hospitals. We hypothesise that Hybrid or ASU models will best address the needs of surgeons and registrars in these areas.

2. METHODS

In this cross-sectional study, Australian Institute of Health and Welfare (AIHW) data were used to identify Australian public hospitals offering elective general surgery (320). Small, children's, unpeered and private sites were excluded. Small hospitals (<2,000 admissions per year of any type, including medicine and surgery) generally employ too few surgeons to have capacity to dedicate one to EGS patients.

Acute Surgical Units were defined as those with a surgeon dedicated solely to the assessment and management of EGS patients for ≥50% of business hours. A Hybrid model lacked such surgeon allocation but provided a registrar rostered solely to EGS patients for ≥50% of business hours, or two or more half-day protected EGS theatre lists per week. Hospitals with a Traditional model had none of these features. Where conflict occurred between responses of a surgeon and registrar from the same hospital, the surgeon's data was viewed as most accurate, except regarding the elective commitments of the registrar, where the registrar's observations were used.

After inter-researcher verbal rehearsal, NK, MT and JH contacted the on-call general surgery registrar and senior surgeon of eligible hospitals by telephone in business hours during March–April 2019. 'Registrars' were doctors rostered to receive EGS referrals, who were not the most senior doctor in that day's EGS on-call hierarchy. They were not required to be referred to as 'registrars' in their hospital, nor enrolled in an accredited training scheme. Eligible 'senior surgeons' were general surgeons who were either the head of the EGS service, the head of the department of surgery, the most senior general surgeon at their hospital or simply available to participate, and were sought in that order. At least three attempts were made to reach each participant. Once contacted, the voluntary and confidential nature of the observational study was explained, then verbal consent to participate was also obtained before delivering the questionnaire. Responses were recorded in writing. No audio was captured, nor inducement offered to participants.

Primary outcomes were the association of EGS model with staff satisfaction and operative exposure. Two measures were used to assess staff satisfaction. Firstly, registrars and surgeons were asked to quantitatively rate satisfaction with their hospital's EGS model on a continuous scale from -2 to +2. Participants were informed that -2 represented '*very dissatisfied*', and +2 '*very satisfied*'. Responses were compared between EGS models. Staff were then asked to qualitatively describe both the positives of their hospital's EGS service and what could be improved. Multiple responses were allowed for each question, and surgeon and registrar responses were pooled. Separately, registrars alone were asked to self-assess their operative exposure using the same continuous scale of -2 to +2, with these values explained to represent non-existent and best possible opportunities, respectively. Logbook data was not requested, as these are non-compulsory for non-accredited registrars, frequently not up-to-date for accredited registrars and the additional steps required for participants to access these would have caused the questionnaire to often exceed the <10minute intended duration.

Secondary outcomes related to current working hours amongst EGS staff. These included longest duration on-duty which included weekdays, on-call rostering more frequently than one-in-four, registrar average hours per day free of work responsibilities and the pooled national average of seniority of medical officer on-call at each time of day. The longest weekday duration on-duty was selected to best examine prolonged rostered on-call simultaneous with elective duties. Elective responsibilities rarely exist on weekends, and so opportunities for rest will be greater in this period. When establishing average hours per week free of work responsibilities for EGS registrars, if both registrars within ('accredited') and external to ('non-accredited') formal surgical training schemes were involved in EGS on-call at a hospital, hours free of work were calculated for both staff types, and the lower figure used. When respondents reported 'day', 'evening' and 'night' shifts without elaborating, these were interpreted as periods 0700-1700, 1700-2100 and 2100-0700, respectively.

This study was approved by the Central Adelaide Local Health Network human research ethics committee (R20180812).

2.1. Statistical analysis

Hospitals were grouped based on EGS structure: Traditional versus Hybrid or ASU, as defined above. Categorical data were displayed as proportions and compared with Pearson's chi-square test, or the Fisher exact test. Continuous data were summarised as means. Divergence from the normal distribution was measured with the Kolmogorov-Smirnov test. For comparisons of continuous data with two normally distributed samples or at least one non-normally distributed sample, analyses were performed using either the Student's T-test or the Mann-Whitney U test, respectively. All statistical tests were two-tailed. The 5% alpha level was used to assess significance.

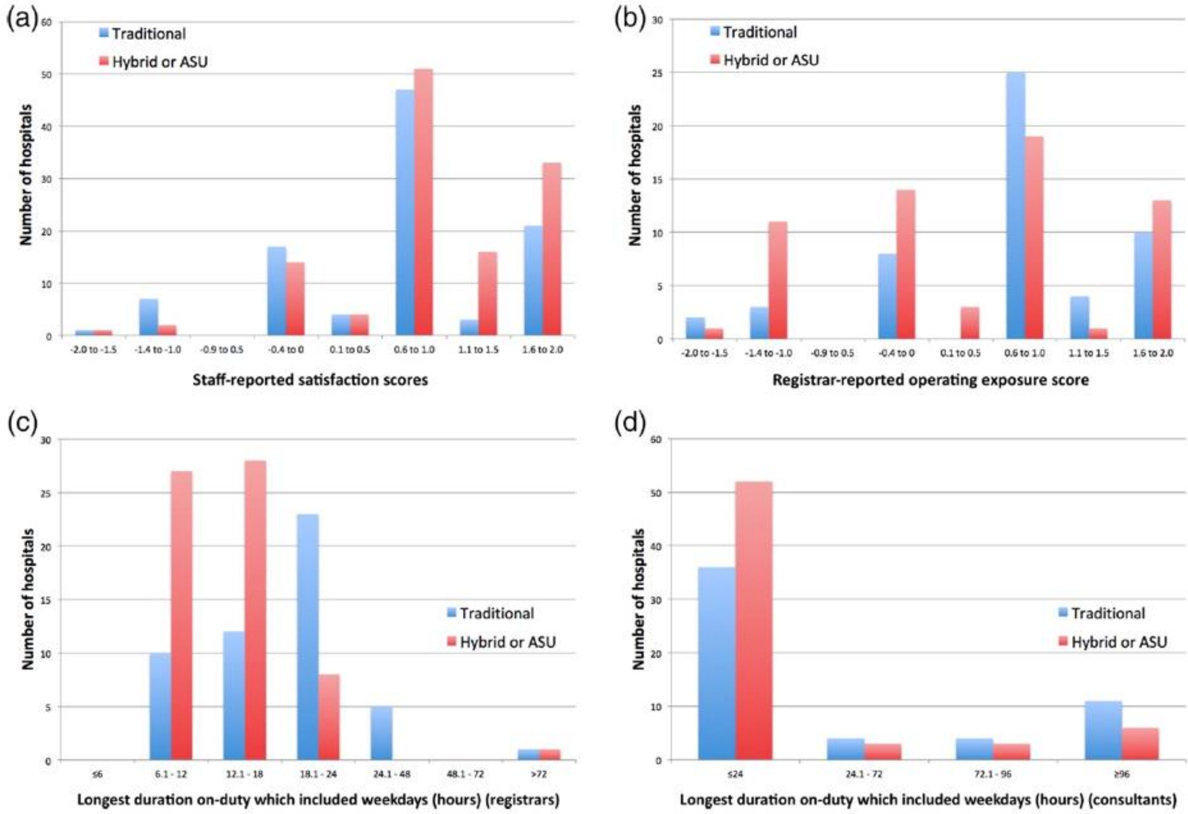
3. RESULTS

AIHW databases revealed 134 medium to major Australian public hospitals performing elective general surgery on adults. Responses identified one further appropriate hospital, which had commenced operation subsequent to the December 2018 AIHW data release. All 135 hospitals were contacted. Fifteen were found not to admit EGS patients at all and were excluded, resulting in 120 eligible sites. At least one staff member was enrolled at 119 hospitals (99%), including 107 of 120 (89%) senior surgeons and 115 of 116 (99%) registrars (of whom 77 (65%) were unaccredited registrars), with four sites found not to allocate EGS on-call to registrars. 33 (28%) hospitals employed an ASU and 31 (26%) a Hybrid model, while 55 (46%) utilised a Traditional structure. This latter group included four hospitals providing a sub-speciality model. Dedicated daytime EGS operating lists were present in 21 of 33 ASUs (64%) and 16 of 31 (52%) Hybrid models, and by definition were absent in all Traditional structures.

3.1. Primary outcomes

Compared with the traditional structure, quantitative scores for satisfaction with their EGS service were significantly higher for staff working in a Hybrid or ASU model (mean 0.86 versus [vs.] 1.15; p=0.012) (Figure 1a). Regarding qualitative assessment of satisfaction with EGS service, staff working in Traditional vs. Hybrid or ASU structures reported positive aspects on 154 vs. 241 occasions, respectively (Table 1). For both groups, the leading perceived strength of their service was satisfactory access to operating theatres. Staff working within Traditional vs. Hybrid or ASU structure made 146 vs. 167 comments on areas for improvement, respectively. For both groups, the most common reported means for improvement was to commence or increase protected daytime EGS theatre access (Table 2). EGS model did not affect registrar-perceived operative exposure scores (mean 0.85 vs. 0.56; p=0.12) (Figure 1). This remained the case when operative exposure was analysed by accredited (p=0.90) or non-accredited (p=0.13) registrar sub-type.

Figure 1. Distribution of emergency general surgery models by (a) pooled surgeon and registrar satisfaction with their model, (b) registrar reported operating exposure, and longest duration on-duty which included weekdays for registrars (c) and consultants (d).



ASU: acute surgical unit.

3.2. Secondary outcomes

Compared with a Hybrid or ASU model, longest duration on-duty which included weekdays was significantly higher amongst hospitals employing a Traditional structure for both senior surgeons (mean 59 vs. 41 hours; p=0.020) and registrars (mean 22 vs. 15 hours; p=0.0003) (Figure 1). Amongst registrars, rostered weekday on-duty of >20 hours existed at 28/51 (55%) vs. 9/64 (14%) hospitals with Traditional vs. Hybrid or ASU models. On-call rosters more frequent than one-in-four were more likely to occur amongst hospitals utilising a Traditional structure for registrars (26/51 (51%) vs. 18/64 (28%); p=0.012) but not consultants (3/47 (6%) vs. 0/57 (0%); p=0.089).

Mean hours per day free of work responsibilities was obtained for registrars only and was higher amongst those working in Hybrid or ASU models compared with Traditional structures (13 vs. 15 hours; p=0.00002). Responses were used to derive the national rates of EGS first on-call medical officer seniority at each time of day. Averaged across the day, the entity first on-call for EGS patients were unaccredited registrars in 61% of medium- to major- sized Australian public hospitals, followed by accredited registrars (30%), fellows or surgeons (8%) and a separate covering health service (1%).

4. DISCUSSION

The growing workforce shortage of general surgeons performing trauma and EGS on-call has been well documented in Europe, the USA and Australasia (332-334). The reasons for this are many and complex. They include a rise in surgical sub-specialists who are less prepared to manage EGS patients, relatively lower economic reward for EGS care and decreasing surgeon tolerance for long work hours (332, 335, 336). Increasing the satisfaction of registrars and surgeons responsible for EGS services is therefore vital for workforce attraction and retention. Career satisfaction is also the single greatest determinant of retirement age amongst general surgeons (337). This study found ASU or Hybrid models were associated with greater registrar and surgeon satisfaction. Hence, greater promotion of the ASU model may prolong the career longevity of EGS surgeons, and ameliorate predicted workplace shortages.

The ASU model is frequently vaunted to increase EGS staff satisfaction. Although supported by multiple post-hoc questionnaires of registrars (43), surgeons (59, 338) or patients (158), only two comparative studies exist (155, 165). These are each limited to a single hospital or city. Increased satisfaction was observed in 13 Australian EGS surgeons assessed before and after ASU implementation (155). Similarly, a Canadian study enrolled 12 surgeons working in either the ASU of one hospital or the Traditional structure of another, with higher satisfaction observed in the former group (165). Our findings add greater rigour to these previous small or non-comparative studies, and expands the inclusion to a national level. This study represents the largest comparative assessment of the impact of EGS model on surgeon satisfaction and the first to include registrars. Enrolling 119 registrars and 107 senior surgeons, greater quantitative and qualitative measures of satisfaction were observed in hospitals utilising a Hybrid or ASU structure.

Additionally, the qualitative staff responses describing observed EGS model positives and deficiencies provide guidance for departments looking to enhance their EGS service (Table 1, Table 2). The most common desired change across all structures was increased daytime theatre access, which was also the most common existing positive trait reported in ASU or Hybrid models. This suggests that these structures can deliver the most sought-after service characteristic, theatre access. This should encourage general surgical departments sharing these frustrations to consider implementation or expansion of an ASU at their site, if appropriate to local workload and resources. These qualitative responses may also guide quality improvement measures directed at the other leading reported areas for improvement, namely providing staffing adequate to workload, and reducing instances of prolonged on-call.

The RACS recommends surgeon and registrar on-call ratios be no more frequent than one-in-four, and supports the Australian Medical Association's National Code of Practice, whose definitions of hazardous working behaviour include <10 hours continuous break per 24 hour period (61, 112). Amongst surgeons, on-call frequency greater than one-in-four was uncommon in both Traditional and Hybrid or ASU structures. However, for registrars, our findings suggest that hospitals utilising Traditional structures are less likely to meet either of these standards. Half (51%) of these Traditional sites rostered registrar on-call more frequently than one-in-four, and mean registrar time off-duty was 13 hours. Given this average includes weekends and rostered days off, there is a clear indication that registrars working within Traditional structures will frequently receive <10 hours' break per day, placing both them and their patients at risk.

In addition to the frequency of call and protected time off-duty, comprehensive assessment of safe working hours must include duration on-duty. The short term deleterious effects of fatigue on safe performance are well recognised in surgery (222, 223). Additionally, long term adverse effects of chronically disrupted sleep include obesity, diabetes mellitus, cardiovascular disease and cancer (80). We found the average longest rostered duration on-duty which included weekdays reached or exceeded high-risk thresholds (79) for surgeons regardless of EGS model (means 59 vs. 41 hours), and for registrars working in Traditional (mean 22 hours) but not Hybrid or ASU structures (mean 15 hours). These findings are concerning. While workflow on many on-call shifts will allow for adequate sleep, and collegiate departments may provide informal cover for fatigued staff, this rostering clearly sanctions prolonged wakefulness and potentially poor performance during busy periods.

Interestingly, several studies have sought to understand the short term effects of extended wakefulness using the framework of blood alcohol concentration (BAC) (79, 339). A BAC greater than 0.05% is widely accepted as hazardous (340). Impairments in cognitive performance after extended wakefulness of 17-19 hours has been shown equivalent to a BAC of 0.05% (79) and after 20-25 hours equivalent to a BAC of 0.10% (79, 339). This study found that 55% of hospitals utilising a Traditional structure rostered registrars to week-day on-call of >20 hour duration, compared with 14% of those with Hybrid or ASU models. These rosters are likely to lead to diminished cognitive performance in these clinicians.

In light of these findings, general surgical departments should regularly re-examine their rostering of on-call staff to mitigate fatigue. The Australian Parliament's '*Inquiry into Sleep Health Awareness in Australia'*, published April 2019, noted widespread attitudes favourably associating the ability to function on less sleep with 'toughness' (80). Departments must confront these biases and instead approach roster design to deliver the highest possible patient care. The RACS acknowledges that optimal rostering is complex, particularly in smaller centres, but cautions against overly restrictive working hours which may reduce training opportunities (341). In appropriate sites, Hybrid or ASU models may therefore offer an effective solution. In smaller centres better suited to Traditional models, solutions may include roster re-arrangement or proven fatigue countermeasures such as a mid-shift 30-minute nap (342).

This study is limited by its dependence on participating doctors' reporting accuracy. Other limitations include the verbal format of study delivery, which may be more open to misunderstanding by the author or participant than written communication. As described in the Methods section, these concerns were mitigated by at each site asking several of the same questions to both the registrar and surgeon. Additionally, this study assessed the subjective outcome of registrar-perceived operating exposure, and not objective operative data such as logbooks or weekly hours in theatre. Another limitation is potential confounding bias, as other variables may be influencing both the uptake of EGS model and staff satisfaction, perceived operative exposure or working hours at each given site. This study observed a correlation but cannot establish causation.

4.1. Conclusion

Compared with Traditional structures of EGS care, Hybrid or ASU model utilisation was associated with higher surgeon and registrar satisfaction, without sacrificing registrar perceived operative exposure. Rostered duration on-duty in excess of safe thresholds was common amongst surgeons across all models and registrars working within Traditional structures. Registrars in Traditional structures were more likely to exceed the recommended one-in-four on-call ratios, and received fewer hours per day off-duty.

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Table 1. Staff reported positive aspects of emergency general surgery models. †

	Traditional		Hybrid or ASU		
	Reg.	Cons.	Reg.	Cons.	Total
Patient outcomes					
Good theatre access/ short TTT	7	10	21	19	57
Continuity of care	12	4	12	5	33
Rapid patient review	5	6	10	10	31
Most/ all patients seen early by consultant	0	9	2	11	22
Excellent patient care	2	6	1	11	20
Staff outcomes					
Good support for registrars	7	2	12	11	32
Broad non-operative learning	7	5	7	11	30
Good operative learning ± inc. elective	6	1	9	5	21
Reduced after-hours operating	0	4	0	10	14
EGS service characteristics					
Collegiate culture; helpful attitude	3	8	1	9	21
Other	27	23	26	38	114
Total	76	78	101	140	395

ASU: acute surgical unit. Cons.: consultant. ED: emergency department. EGS: emergency general surgery. Inc.: including. Reg.: registrar. TTT: time to theatre. †: Responses received from registrars and surgeons at 119 (99%) and 107 (89%) of 120 eligible hospitals, respectively.

Table 2. Staff reported methods to improve emergency general surgery models. †

	Traditional		Hybrid or ASU		
	Reg.	Cons.	Reg.	Cons.	Total
Change EGS service structure					
Start/ increase protected daytime EGS theatre access	12	23	16	27	78
Commence/ expand ASU service	6	5	5	11	27
Remove tiring ≥36 hour on-call	8	2	6	2	18
Improve operative exposure ± inc. elective	6	0	1	2	9
Divide work more fairly	2	2	3	2	9
More continuity/ less patient handover	2	0	5	2	9
Allocate additional funding					
More EGS staff	7	13	10	13	43
More nursing/ ED/ anaesthetic/ radiology staff	4	5	0	4	13
More EGS beds	1	3	0	9	13
Change staff behaviours					
Remove barriers to after-hours theatre access	4	5	1	3	13
Other	21	15	18	27	81
Total	73	73	65	102	313

ASA: American Society of Anesthesiologists physical status score. ASU: acute surgical unit. Cons.: consultant. ED: emergency department. EGS: emergency general surgery. ICU: intensive care unit. Inc.: including. No.: number. Reg.: registrar. VMO: visiting medical officer. †: Responses received from registrars and surgeons at 119 (99%) and 107 (89%) of 120 eligible hospitals, respectively.

Chapter 8: Publication 7

A systematic review of dedicated models of care for emergency urological patients

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Principal Author

Name of Principal Author (Candidate)	Ned Kinnear		
Contribution to the Paper	Performed literature searches, screened results, assessed risk of bias, performed data analysis, wrote manuscript first draft and acted as corresponding author.		
Overall percentage (%)	50%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/12/21

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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ABSTRACT

Objective: To systematically evaluate the spectrum of models providing dedicated resources for emergency urological patients (EUPs).

Methods: A search of Cochrane, Embase, Medline and grey literature from January 1, 2000 to March 26, 2019 was performed using methods pre-published on PROSPERO. Reporting followed Preferred Reporting Items for Systematic Review and Meta-analysis guidelines. Eligible studies were articles or abstracts published in English describing dedicated models of care for EUPs, which reported at least one secondary outcome. Studies were excluded if they examined pathways dedicated only to single presentations, such as torsion, or outpatient solutions, such as rapid access clinics. The primary outcome was the spectrum of models. Secondary outcomes were time-to-theatre, length of stay, complications and cost.

Results: Seven studies were identified, totalling 487 patients. Six studies were conference abstracts, while one study was of full-text length but published in grey literature. Four distinct models were described. These included consultant urologists allocated solely to the care of EUPs ("Acute Urological Unit") or dedicated registrars or operating theatres ("Hybrid" structures). In some services, EUPs bypassed emergency department assessment and were referred directly to urology ("Urological Assessment Unit") or were managed by other dedicated means. Allocating services to EUPs was associated with reduced time-to-theatre, length of stay and hospital cost, and improved supervision of junior medical staff.

Conclusion: Multiple dedicated models of care exist for EUPs. Low-level evidence suggests these may improve outcomes for patients, staff and hospitals. Higher quality studies are required to explore patient outcomes and minimum requirements to establish these models.

Keywords: Acute surgical unit; Acute care surgery; Urology; Emergency; Acute; Dedicated.

1. INTRODUCTION

Emergency urological patients (EUPs) represent a significant patient cohort in clinical practice. They comprise >2% of emergency department presentations (343-345) and up to 30% of all urology inpatient admissions (346). Traditionally, these patients have been assessed and managed ad-hoc. Urological surgeons and trainees were rostered during business hours to elective duties, with EUPs seen in-between or afterwards. This created predictable inefficiencies, including delays for both acute and elective patients and frequent after-hours operating, which is detrimental to patients and surgeons (223, 347, 348).

In general surgery, discontent with similar conventional structures led to the introduction of the Acute Surgical Unit (ASU) (3, 190). A central component of the ASU model is a dedicated surgeon allocated for emergency general surgery patient care. Additionally, trainees may be rostered to staff the ASU service and quarantined emergency operating theatres made available. The model is associated with reduced time to theatre, reduced operating after-hours, fewer complications and shorter length of stay (163, 212). In urology, increasing numbers of emergency patients have led to calls for similar reform (343, 349, 350). However, innovation for EUPs remains in its infancy, and there is a relative dearth of data on this topic. There are no systematic reviews on these dedicated models of care for EUPs.

In this review, we aim to describe the spectrum of dedicated models of care for EUPs published in the literature. We hypothesize that these systems will improve the timeliness of care and be equivalent or superior in other measures.

2. METHODS

2.1 Search strategy

A systematic search of Cochrane Central Register of Controlled Trials (CENTRAL), Embase and Medline was conducted in April 2019. Searches limited studies to the period January 1, 2000 and March 26, 2019, and utilized Boolean operators as follows: (OR: Acute care urol*, acute care surg*, acute urol*, acute surg*, emergency urol*, emergency surg*, surgical assessment, dedicated, protected) and (OR: Department, pathway, program, service, system, team, unit) and (OR: Urology, urological).

Grey literature was also assessed. This included allowing the inclusion of relevant unpublished studies (including conference abstract proceedings) that were identified in the above database searches, and reviewing the bibliographies of eligible studies. The list of retrieved studies is available in Appendix 9. The process for identifying and evaluating data complied with the Preferred Reporting Items for Systematic Reviews and Meta-analyses criteria (351) (Figure 1). This included pre-publication of our intended search method analysis on PROSPERO (CRD42019130225). Identified studies were screened sequentially by title, abstract and full-text review, with ineligible results removed at each step. Eligible studies then underwent data extraction and review of references. Two authors (NK and MH) independently screened results and performed data extraction, using a pre-defined form (Appendix 10). For accuracy, data were extracted twice. Disagreements were resolved by discussion. There was a consensus amongst all authors concerning the inclusion criteria and the final list of included articles.

2.2 *Inclusion and exclusion criteria*

Criteria for study eligibility followed the patient population, intervention, comparator, outcome and study method (PICOS) (351). Eligible studies assessed EUPs (P), had a cohort receiving care from dedicated resources (I), may or may not have utilized a comparator group (C) and reported outcomes from a sample of solely EUPs on at least one of timeliness of care, length of stay, complications or cost (O). Eligible studies were original and published in English (S).

The first studies allocating resources to emergency general surgical patients were published in 2001 (3), with subsequent consideration of urological versions. While there have been successful examples of pathways introduced to expedite care for patients with specific presentations, such as renal colic (352, 353) or acute scrotum (354), these do not offer benefit to the majority of EUPs. Hence, studies were excluded if they were published before the year 2000 or in a language other than English, failed to describe at least one outcome from a sample of purely EUPs, or documented pathology-specific or outpatient solutions, such as torsion or rapid access clinics, respectively.

2.3 *Intended analyses*

The primary outcome was the spectrum of models. Secondary outcomes were time to theatre, length of stay, complications and cost. All relevant studies were summarized qualitatively. We anticipated finding insufficient studies for quantitative assessment, so this was not planned. However, studies with similar models of care were presented together. The Acute Urological Unit was defined as one in which a consultant urologist was dedicated each day to EUPs, without elective or private commitments. A hybrid structure did not meet this requirement but benefited from either a urology registrar allocated solely to emergency patients or protected operating theatre access. Distinct from these options, services which managed EUPs without the involvement of emergency department physicians were classified as Urological Assessment Units. Services separate from the above three categories were described individually. If instances of unreported results were encountered, such as absent patient sample size, at least two attempts were made to contact study authors by email to clarify.

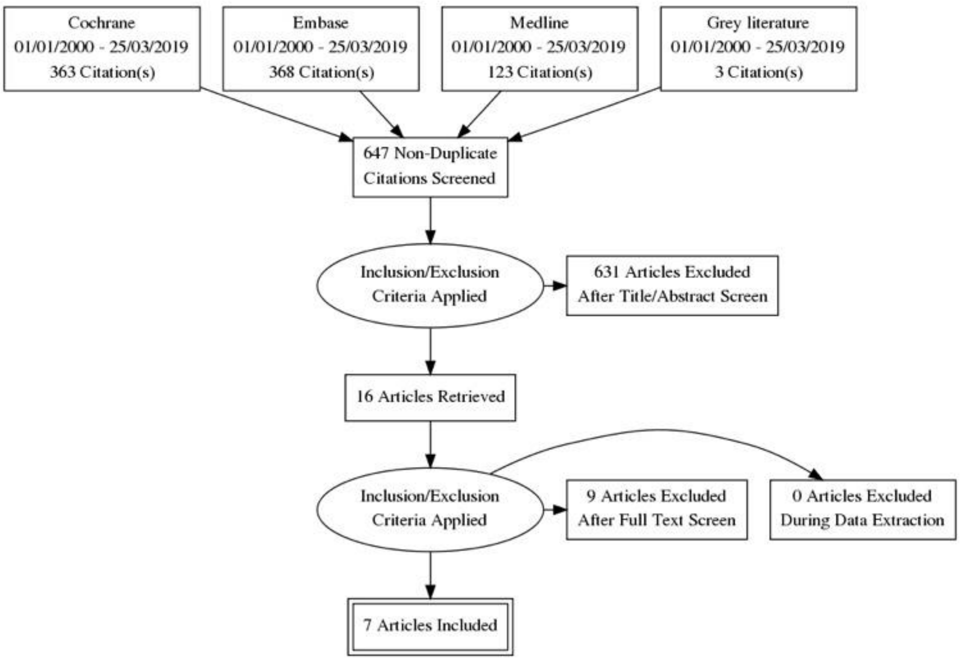
2.4 Bias

Tools to assess study quality were tailored to study design (355). The authors did not expect to identify any randomized controlled trials. Subsequently, risk of bias for (comparative) cohort studies was assessed utilizing the Newcastle-Ottawa Scale, as prescribed by the Cochrane Handbook (356, 357). For non-comparative case series, study quality was measured with the modified Delphi checklist, as recommended by a recent systematic review of quality assessment tools (358, 359). Given the expected nature of included studies, three of nine items on the Newcastle-Ottawa Scale were inapplicable and not scored, as were three of eighteen modified Delphi criteria. Study quality was independently assessed by two reviewers (NK and MH) against pre-defined criteria (Appendix 11). Disagreements were resolved by discussion. Risk of bias was not used to exclude studies. We anticipated identifying too few studies to assess publication bias.

3. RESULTS

A total of 854 studies were found on database searches, with an additional three identified from bibliographies and other grey literature (Figure 1). After removal of 210 duplicate results and 631 irrelevant studies, 16 articles were retrieved for full-text review (Appendix 9). From these, seven eligible publications were selected, totaling 487 patients (360-367) (Table 1). However, this sum represents an under-estimate, with three studies reporting samples of undefined size. All publications were non-randomized single-centre studies. Only one full-length article met the eligibility criteria (367). This was published in grey literature (electronic bulletin) and not indexed on the pre-specified databases. All other studies were available as abstract only, representing a low level of evidence. Database searches were performed for all authors of all included studies but did not reveal any instances of these abstracts proceeding to full-text articles.

Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow diagram.



3.1. Study design

Two included studies were non-comparative case series of patients following introduction of dedicated emergency urological services (361, 365), while the remaining five were comparative cohort studies, describing patient groups before and after such changes (362-364, 366, 367). Four studies were prospective (361, 365-367), and three retrospective (362-364). There was a substantial disparity in the studies' chosen enrolment moment within the patient journey. Two studies each assessed EUPs who had either presented to the emergency department (361, 364), been admitted (362, 367) or proceeded to the theatre (363, 365), while one study assessed those with symptomatic renal calculi requiring surgery (366). Similarly, patient enrolment period varied from 2–24 months (361-363, 365, 367), with two studies not reporting duration (364, 366). No studies described the use of statistical tests or *p* values.

3.2. Primary outcomes

Four distinct dedicated models of care for EUPs were observed (Table 1). Two studies described introducing Acute Urological Units, with a consultant urologist allocated solely to EUPs (364, 367). Russell *et al.* (367) reported the commencement of a daily ward round of all inpatients and referrals, while Golda *et al.* (364) assess the creation of a full time position dedicated to EUPs, both staffed from a rotating pool of urologists. The latter also included three half-day operating lists per week allocated to EUPs. Three publications reported establishing Hybrid models of care for EUPs. Raza *et al*. [26] describe amending rosters to provide a full day urology registrar for emergency patients, while two other studies introduced protected emergency urology operating theatre access of either two half-day lists per week or unspecified quantity (365, 366). The commencement of a Surgical Assessment Unit was documented by Nic an Riogh *et al.* [24], within which emergency patients with suspected surgical diagnoses (including general surgical, urological and other) were triaged directly to dedicated "senior" surgical staff, bypassing the emergency department. Lastly, Tharakan *et al.* [25] described a separate solution. In a service traditionally placing responsibility for assessing and admitting EUPs on senior house officers not yet in formal urological training (e.g. "un-accredited" registrars), this study introduced extended on-site evening shifts for accredited urology registrars to supervise the process.

3.3. Secondary outcomes

3.3.1. Time to theatre

Two studies reported decreased time to theatre for EUPs following commencement of hybrid services. Compared with conventional models, mean time to theatre improved from 7 h to 3 h in one study including all EUPs (363), and from 56 h to 13 h in another assessing only those with symptomatic urolithiasis (366).

3.3.2. Length of stay

Four studies reported data on length of stay. Mean length of stay decreased in one study from 4.6 days to 2.1 days for all EUPs following the introduction of an Acute Urological Unit model (367), and from 5.2 days to 2.8 days amongst renal colic patients after the establishment of a Hybrid structure (366). In a separate study, the commencement of a hybrid structure did not alter the length of stay (data not provided) (363). A non-comparative case series of EUPs of any diagnosis treated within a Surgical Assessment Unit reported a median length of stay of 2 days (361).

3.3.3. Cost

Two studies of Acute Urological Units reported financial results. In 2012, a study from the United Kingdom extrapolated reductions in length of stay to estimate annual savings of £502 000 for an "average district general hospital" (367). Separately, a Canadian study of unspecified enrolment duration stated that "the financial impact analysis on the hospital has been neutral to favourable", without providing further data (364).

3.3.4. Other findings

Eligible publications sporadically reported various hospital, patient and staff outcomes. Regarding benefits to hospitals, Golda *et al*. [27] observed that establishment of their acute urological unit was associated with reduced emergency department length of stay (data not stated) (364). One cohort study describing the introduction of a hybrid model with a dedicated registrar for EUPs found emergency theatre utilisation improved by 51% (363). Separately, in a service where the after-hours assessment of EUPs was the responsibility of more junior house officers, extending accredited urology registrar shift duration was associated with the proportion of emergency urological admissions deemed preventable decreasing from 29% to 11% (362). Regarding patient outcomes, a non-comparative case series of EUPs undergoing surgery found that following commencement of a Hybrid model, a urologist was present in theatre for all cases and only 3% of patients suffered Clavien-Dindo Grade III-IV complications (365).

3.4 Assessment of bias

The existence of eligible research in predominately abstract form substantially hindered assessment of bias, as descriptions of method were very limited. Utilizing the Newcastle-Ottawa Scale, the risk of bias was medium to high for the five comparative cohort studies (Table 2). Similarly, the modified Delphi criteria suggested the two non-comparative case series were of only medium quality (Table 3). None of the seven studies described the presence or absence of patient exclusions, ethics approval, conflicts of interest or funding. Reporting bias may be present, with only one study providing data on complications (365). Publication bias was not assessable due to the low number of similar studies.

4. DISCUSSION

Efforts to pro-actively allocate resources to emergency patients began in general surgery >20 years ago (3, 190, 212). The driving forces behind this modernization were significant need and sufficient staff pool to allow re-structuring. General surgery's elective activities within traditional models of care were particularly prone to interruption, due to caring for more than twice as many emergency patients as any other surgical specialty (81). Local forces such as governmental targets to limit patient time in the emergency department have also incentivized surgical staff allocation to emergency patients (60, 368). Additionally, there are more general surgeons than any other type (369), providing capacity to dedicate separate personnel in the ASU model. It is anticipated that these models will spread to other surgical specialties when similar patient and staff number are reached. Furthermore, this type of restructuring may benefit emergency patients in urology more than other sub-specialties, as evidence suggests EUPs suffer the greatest delays while awaiting theatre (370).

This first systematic review of dedicated models of care for EUPs suggested that they may offer many benefits. Patients may experience reduced time to theatre and length of stay. The mean time to theatre improved from 7 h to 3 h in one study including all EUPs and from 56 h to 13 h in another assessing only those with symptomatic urolithiasis (363, 366). Mean length of stay decreased in from 4.6 days to 2.1 days for all EUPs and from 5.2 days to 2.8 days amongst renal colic patients following the introduction of an Acute Urological Unit and hybrid model, respectively (366, 367). In one study, this resulted in an estimated annual savings of £502 000 (USD $632 000) (367). Finally, junior doctors may enjoy greater supervision both in the emergency department and operating theatre (362, 365).

From the above is clear that dedicated emergency urological models of care may be beneficial for both patients and hospitals. Further demonstration of the spread of these structures is provided by full-text articles which did not meet inclusion criteria. In the United Kingdom, Mohamed et al. (371) presented an eight-week audit of their Surgical Assessment Unit. While their sample included 119 EUPs, no outcomes were given for this sub-group. Separately, a French language case series described 1 257 patients treated in their Acute Urological Unit in 2009 (372).

A urological department considering introducing dedicated models of care for EUPs must assess their EUP load, staff pool and implications for training. Included studies observed benefit from dedicated models implemented in centres with annual EUP load of ~500 admissions (367) and ~300 procedures (361). They suggested the minimum required number of urologists was five to six (364, 367), identical to the number of general surgeons reported necessary to staff an ASU (3, 323, 373). While none of the identified urological studies described barriers to change, insight may continue to be gained from general surgery. Amongst hospitals without dedicated models for emergency general surgical patients, reported concerns to their introduction include insufficient patient load or surgeon pool and beliefs that patients with complex emergencies such as perforated diverticulitis will receive superior care in sub-specialty rather than ASU on-call systems (323, 374). Hospitals post-ASU implementations have rarely reported disadvantages. However, those described include the requirement for on-call consultants to hold no elective duties creating difficulty in roster swaps, and anecdotal reports that the remuneration for ASU practice does not cover income lost in forfeiting other activities (166). Additionally, ASU start-up funding is typically required before subsequent potential cost-neutrality or savings may be realized (162, 193). Finally, the identified studies provide limited evidence that dedicated models of care benefit urological trainees, insofar as increased supervision (362, 365).

This review is limited by the low level of evidence of the eligible studies, and its findings should be interpreted with substantial caution. All included studies have been subjected to only the scrutiny required for conference presentation or electronic bulletin inclusion, with none undergoing formal journal peer-review. Small or unreported sample sizes and lack of any statistical analyses further undermine these studies.

4.1. Conclusion

This review demonstrates early attempts within urology to emulate the successes of general surgeons in pre-emptively allocating resources to emergency presentations. It provides low-level evidence that similar models in urology may improve outcomes for patients, staff and hospitals. Further studies are needed to assess comparative patient and financial outcomes and establish the minimum requirements of these models.

TABLES

Table 1. Eligible studies.

Year	First author	Country	EUP cohort	Design	Care structure		Enrolment (month)		Patients (*n*)		Demo-graphics	TTT (h)	LOS (day)	Cost	Other results	Throughput (*n*/week)
					Trad.	Interv.	Trad.	Interv.	Trad.	Interv.						
2012	Russell (360, 367)	UK	Admitted	Prosp.	Registrar-delivered ward service	Consultant-delivered ward service	12	12	–	–	–	–	Δ 4.6 to 2.1	£502,000 saving p.a.	–	–
2015	Nic an Riogh (361)	Ireland	ED	Prosp.	ED reviews all surgical patients	SAU reviews all surgical patients		4		101	N.a.	–	2 †	–	–	6
2015	Tharakan (362)	UK	Admitted	Retro.	Urology registrar on-site until 8pm	Urology registrar on-site until 10pm	1	1	–	77	–	–	-	–	‡	6
2016	Raza (363)	UK	Surgery	Retro.	Registrar has all-day elective duties	Registrar rostered all-day solely to EUPs	1	1	50	73	–	Δ 7 to 3	Same §	–	||	14
2017	Golda (364)	Canada	ED	Retro.	Consultant & theatre rostered all day to elective duties	A consultant rostered solely to EUPs, & 3 half-day EUP theatre lists/ week	–	–	–	–	–	–	–	¶	††	–
2017	Narra (365)	Australia	Surgery	Prosp.	No dedicated EUP theatre lists	2 half-day EUP theatre lists/ week		8		70	N.a.	–	–	–	‡‡	2
2018	Hegazy (366)	Ireland	Urolithiasis	Prosp.	No EUP pathways & limited emergency theatre capacity	Specified EUP pathways & increased emergency theatre capacity	2 ∫	2 ∫	58 ∫	58 ∫	–	Δ 56 to 13	Δ 5.2 to 2.8	–	–	7

ED: emergency department; EUP: emergency urological patients; Interv.: intervention group; LOS: change in mean length of stay; N.a.: not applicable; p.a.: per annum; Prosp.: prospective; Retro.: retrospective; SAU: Surgical Assessment Unit; Trad.: traditional group; TTT: change in mean time to theatre; UK, United Kingdom. –: outcome not reported; Δ: change from; £: Great British Pounds; †: median; ‡: the proportion of emergency urological admissions deemed 'inappropriate' decreased from 29% to 11%; §: data not provided; ||: utilization of the emergency theatre increased 51%; ¶: the financial impact analysis on the hospital has been neutral to favourable, however data not provided; ††: emergency department length of stay decreased, however data not provided; ‡‡: two patients suffered Clavien-Dindo III complications, and a consultant was present in theatre for all procedures; ∫: data *via* personal communication with authors, with thanks.

Table 2. Assessing risk of bias amongst comparative cohort studies with the Newcastle-Ottawa Quality Assessment Scale.

Year & first author	Selection Representative-ness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability Comparability of cohorts on the basis of the design or analysis	Outcome Assessment of outcome	Was follow-up long enough for outcomes to occur?	Adequacy of follow up of cohorts	Total quality scores
2012 Russell (360, 367)	*	*	-	N.a.	–	–	N.a.	N.a.	2
2015 Tharakan (362)	*	-	*	N.a.	–	*	N.a.	N.a.	3
2016 Raza (363)	*	*	*	N.a.	–	*	N.a.	N.a.	4
2017 Golda (364)	-	-	-	N.a.	–	–	N.a.	N.a.	0
2018 Hegazy (366)	*	*	-	N.a.	–	–	N.a.	N.a.	2

Studies scoring 0–2, 3–4 and 5–6 points were identified as high, medium and low quality, respectively.
N.a.: not applicable; *: indicates one point; **: indicates two points.

Table 3. Assessing risk of bias amongst non-comparative cases series with the Modified Delphi criteria checklist.

Year & first author	Study objective	Study population					Intervention (s)		Outcome measure			Statistical analysis	Results and conclusions					Competing interests	Total score
	Cr 1	Cr 2	Cr 3	Cr 4	Cr 5	Cr 6	Cr 7	Cr 8	Cr 9	Cr 10	Cr 11	Cr 12	Cr 13	Cr 14	Cr 15	Cr 16	Cr 17	Cr 18	
2015 Nic an Riogh (361)	*	*	–	*	*	*	*	N.a.	*	*	N.a.	–	N.a.	–	–	–	–	–	8
2017 Narra (365)	*	–	–	*	*	–	*	N.a.	–	*	N.a.	–	N.a.	–	–	*	–	–	6

See Appendix 11 for details of the eighteen criteria. Studies scoring 0–5, 6–10 and 11–15 points were identified as high, medium and low quality, respectively.
Cr: criterion; N.a.: not applicable; *: indicates one point.

Chapter 9: Publication 8

The acute surgical unit: an updated systematic review and meta-analysis

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ii. permission is granted for the candidate in include the publication in the thesis; and

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ABSTRACT

Objective: To systematically review comparative studies on the acute surgical unit (ASU) model.

Methods: Searches were performed of Cochrane, Embase, Medline and grey literature. Eligible articles were comparative studies of the ASU model published 01/01/2000-12/03/2020. Amongst patients with any diagnosis, primary outcomes were length of stay, after-hours operating, complications and cost. Secondary outcomes were time to surgical review, time to theatre, mortality and re-admission for patients with any diagnosis, and cholecystectomy during index admission for patients with biliary disease. Additional analyses were planned for specific cohorts, such as patients with appendicitis or cholecystitis.

Results: Searches returned 9,677 results from which 77 eligible publications were identified, representing 150,981 unique patients. Cohorts were adequately homogenous for meta-analysis of all outcomes except cost. For patients with any diagnosis, compared with the Traditional model, the introduction of an ASU model was associated with reduced length of stay (mean difference [MD] 0.68 days; 95% confidence interval [CI] 0.38-0.98), after-hours operating rates (odds ratio [OR] 0.56; 95% CI 0.46-0.69) and complications (OR 0.48, 95% CI 0.33-0.70). Regarding cost, two studies reported savings, while one found no difference. Amongst secondary outcomes, for patients with any diagnosis, ASU commencement was associated with reduced time to surgical review, time to theatre and mortality. Re-admissions were unchanged. For patients with biliary disease, ASU establishment was associated with superior rates of index cholecystectomy.

Conclusion: Compared to the Traditional structure, the ASU model is superior for most metrics. ASU introduction should be promoted in policy for widespread benefit.

Keywords: Acute surgical unit; emergency surgery; general surgery; appendicectomy; cholecystectomy; cost.

1. INTRODUCTION

Within general surgery, emergency presentations comprise the majority of admissions, deaths and cost (73). Annually, emergency general surgery admissions exceed 600,000 in the United Kingdom (UK), three million in the United States of America (USA), and cost the latter USD $30 billion (49, 319). In the traditional structuring of general surgical departments, staff assessed and managed emergency presentations ad hoc, in competition with outpatient and elective operative commitments. This invariably led to interruption or cancellation of elective patients, or delays in emergency patient care, with frequent after-hours operating. Dissatisfaction with these circumstances led to the introduction in 1996 of separate teams for emergency and elective general surgical patients (3).

The central tenet of this model was a general surgeon allocated solely to the care of emergency patients, on-site in business hours and on-call after-hours. Additional features have included dedicated registrars, operating theatre lists and hospital beds (58). This model's various names include 'acute surgical unit' (ASU), 'acute general surgical unit' and 'acute care surgery' (ACS). The success of this approach led to its spread internationally, and replication in other surgical specialties (375, 376). Multiple studies have associated ASU model introduction with positive outcomes, including reduced time to theatre, length of stay and complications (51, 153, 163, 295). However, model uptake remains slow, perhaps due to persisting equipoise regarding the model's clinical and financial benefits.

Previous systematic reviews have attempted to address this uncertainty (58, 375). However, these have often had narrow foci, and have become outdated by the expanding number of studies. Therefore, this review aims to summarise current literature regarding the impact of the ASU structure on outcomes for patients, staff and healthcare systems. We hypothesise that ASU introduction is associated with reduced length of stay, after-hours operating rates, complications and cost, and superior or equivalent to the Traditional model in other relevant metrics.

2. METHODS

2.1 Search strategy

A systematic search of Cochrane Central Register of Controlled Trials (CENTRAL), Embase and Medline was conducted in March 2020. Searches were performed by Title or Abstract, utilising keywords, truncations and Boolean operators as follows: (acute care general surg*, acute care surg*, acute general surg*, acute surg*, emergency general surg* OR emergency surg*) AND (department, model, pathway, program, service, system, team OR unit) AND (charges, complications, cost, hours, length of stay, mortality, outcome OR readmission). Grey literature was eligible and comprehensively searched, by review of the above search results, bibliographies of retrieved articles and proceedings of the 2010-2019 annual scientific conventions of the Royal Australasian College of Surgeons. For identified potentially eligible works, study authors were contacted to attempt to resolve instances of unclear outcome data.

Our method for identifying and evaluating data complied with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) criteria and has been reported in line with the Assessing the methodological quality of systematic reviews (AMSTAR) Guidelines (351) (Appendix 12). This included pre-publication of our intended analysis on PROSPERO (CRD42019126942). Identified studies were screened by title and abstract, followed by full text review. Articles then progressed to data extraction, including review of references. Two independent authors (NK, SJ) performed study screening and data extraction, using a pre-defined form (Appendix 13). The final list of included articles was determined by compliance with the inclusion criteria and with the consensus of all authors.

2.2 Inclusion criteria

Inclusion criteria were determined via the patient population, intervention, comparator, outcome and study (PICOS) method (377). Eligible studies assessed emergency general surgery admissions of adult subjects without age restriction (P), had a cohort managed within an ASU (I), a comparator cohort managed within a Traditional model (C), and reported at least one of the pre-defined primary or secondary outcomes (see below) (O). Eligible studies were original, written in English and published 01/01/00 – 12/03/20 (S). Additionally, studies were required to report duration of observation period and raw numbers of patients in each cohort, although no minimum values were necessary for inclusion.

Exclusion criteria were non-comparative studies, lack of original raw data, inclusion of elective surgical patients, failure to report any of the selected primary or secondary outcomes, sole assessment of emergency general surgery age-based sub-populations such as patients aged >65 years, or failing to assess the impact of introducing an ASU type model. Examples of the studies excluded by the latter criterion include studies of surgical assessment units, introduction of pathways for a single pathology such as cutaneous abscesses, and studies comparing outcomes between Traditional and ASU models at different hospitals, rather than within institutions which changed to an ASU. If multiple studies overlapping samples of the same pathology from the same site, only the largest sample was included for meta-analysis.

2.3 Intended analyses

Amongst patients with any emergency general surgical diagnosis, primary outcomes were length of stay, after-hours operating rates, complications and cost, while secondary outcomes were time to surgical review, time to theatre, short term mortality rates and re-admission rates. Rates of cholecystectomy on index admission were also assessed for patient cohorts with acute biliary disease. Additional analyses were planned for presentation in appendices, regarding studies reporting the above outcomes in cohorts with restricted diagnoses, such as appendicitis, biliary disease, gallstone pancreatitis, small bowel obstruction or diverticulitis. These supplementary analyses were performed by pathology sub-group and only if ≥3 cohorts were identified with similar methodology.

Qualitative summary was intended for all data. Quantitative syntheses (meta-analyses) were planned for all primary and secondary outcomes. Inter-study variations were expected in outcome definitions, such as after-hours periods, nature of complications reported, cost calculations and time to surgical review or theatre. Each work's definitions were to be reported, and not used for study exclusion.

When available, cost data for each cohort were converted to United States dollars using publically available currency exchange rates on the date of each study's publication. Meta-analysis was performed in Review Manager Software version 5.3 (the Nordic Cochrane Centre, the Cochrane Collaboration, Copenhagen, Denmark). For each study included in the meta-analysis, the number of cases and controls, and outcomes per group were extracted. Pooled analyses were presented as pooled mean difference (MD) for continuous variables such as length of stay, and as odds ratios (OR) for categorical variables such as complications. Random effects analysis was used throughout. Funnel plots were used to assess publication bias for each meta-analysis. All analyses were two-tailed, and significance was assessed at the 5% alpha level.

2.4 Bias

The authors did not expect to identify any RCTs. As such, risk of bias was assessed with the Newcastle-Ottawa Scale, in accordance with the Cochrane Handbook (356, 357). Two reviewers (NK, DH) independently assessed each study according to pre-defined guidelines (Appendix 14). Disagreements were resolved by consensus. Studies were not excluded on the basis of risk of bias. Publication bias was assessed with funnel plots.

3. RESULTS

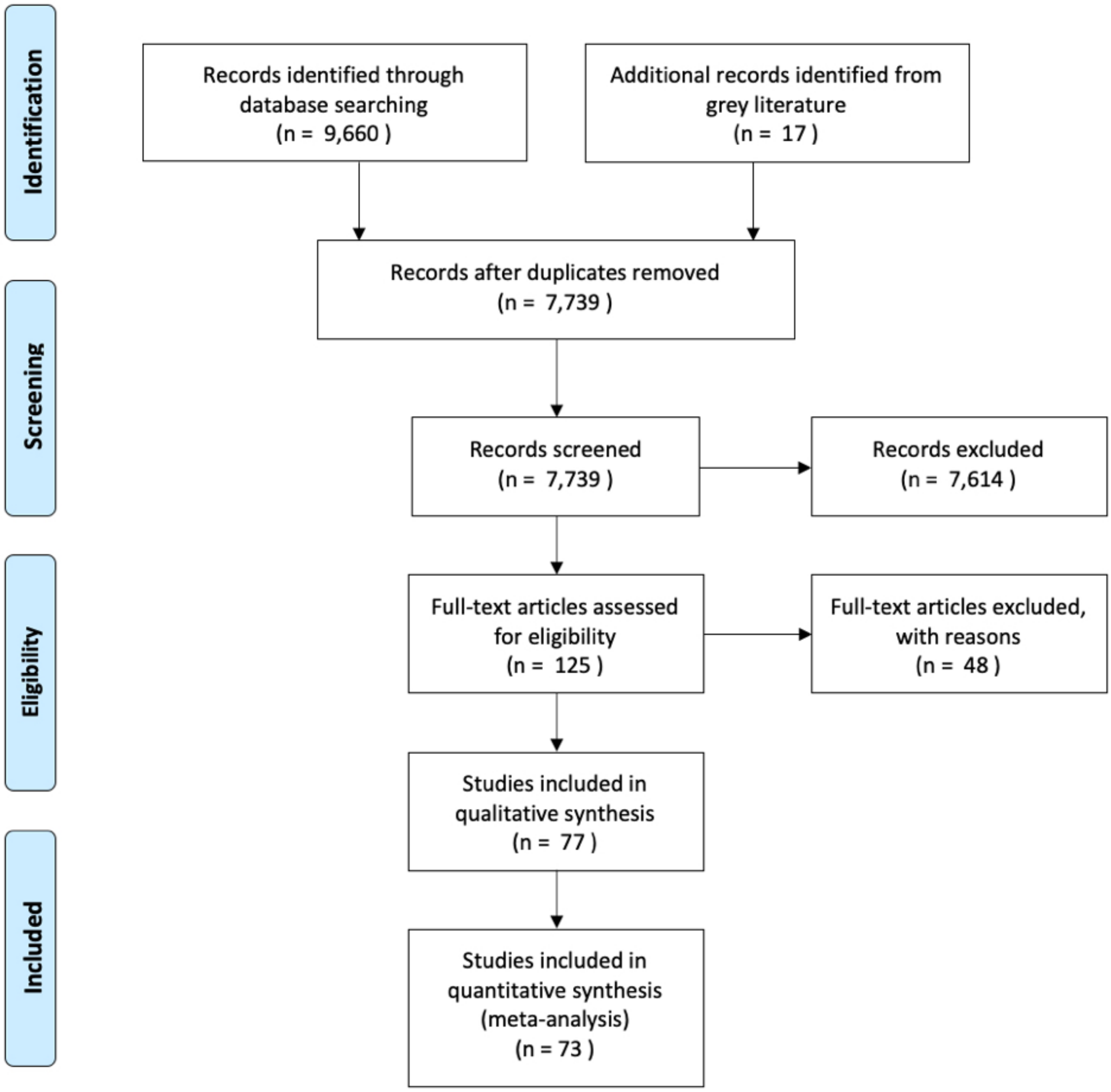
Database searches returned 9,660 results, with an additional 17 studies identified from grey literature. After removal of duplicate results, 7,739 unique studies were screened by Title and then Abstract. After exclusion of irrelevant or ineligible results, 125 studies were retrieved for full text review (Appendix 15). Titles were eliminated if they did not assess introduction of an ASU (twenty titles) or report raw patient data for pre-defined primary or secondary outcomes (ten), were a systematic review (six), overlapped with a larger study from the same site (five), lacked a pre-ASU comparator cohort (four) or included elective patients in their cohorts (three). Finally, 77 studies were found to fulfill all eligibility criteria (3, 40-44, 51, 76, 102, 120, 121, 125-128, 130-139, 150-166, 177-180, 183-189, 191, 193-201, 204, 205, 209, 378-388) (Figure 1). These encompassed 61 sites in thirteen nations, and represented 150,981 unique patients (Table 1). While a minority of works commenced their study upon ASU establishment and prospectively registered patients within that model, all can be considered retrospective cohort studies in that patients treated within Traditional structures were retrospectively enrolled. Cohorts had adequately homogenous methodology for performance of quantitative syntheses of the impact of introduction of an ASU on all outcomes except cost. Primary and secondary outcomes are presented below, while additional analyses for pathology-specific cohorts, such as appendicitis and cholecystitis, are detailed in Appendix 16. Meta-analysis forest plots for secondary outcomes and all sub-group analyses are provided in Appendix 17. Inter-study variations in outcome definitions are reported in Table 2.

3.1. Primary outcomes

Length of stay

Length of stay amongst cohorts with any diagnosis was reported for 114,927 patients in sixteen studies (40, 41, 43, 44, 76, 102, 133, 150-158). Introduction of an ASU was associated with a mean reduction in length of stay of 0.68 days (95% confidence interval [CI] 0.38-0.98, p<0.0001) (Figure 2).

Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow diagram.



After-hours operating

The proportion of procedures performed after-hours amongst cohorts with any diagnosis was reported for 26,578 patients in eleven studies (3, 41, 133, 155, 157, 161-166). Compared with a Traditional model, establishing an ASU was associated with reduced rates of after-hours operating, with an odds ratio of 0.56 (95% CI 0.46-0.69, $p<0.00001$).

Complications

Complication rates were reported for cohorts with any diagnosis were available for 11,584 patients in four studies (40, 44, 133, 154). ASU introduction was associated with reduced complications, with an odds ratio of 0.48 (95% CI 0.33-0.70, p<0.0001).

Cost

Cost comparisons for cohorts with any diagnosis were reported in three studies comprising 4,509 patients (41, 154, 161). ASU introduction was associated with significant savings in two works (154, 161), while another cohort found costs unchanged (Table 1). Meta-analysis was not possible due to varying cost quantification methodology.

3.2. Secondary outcomes

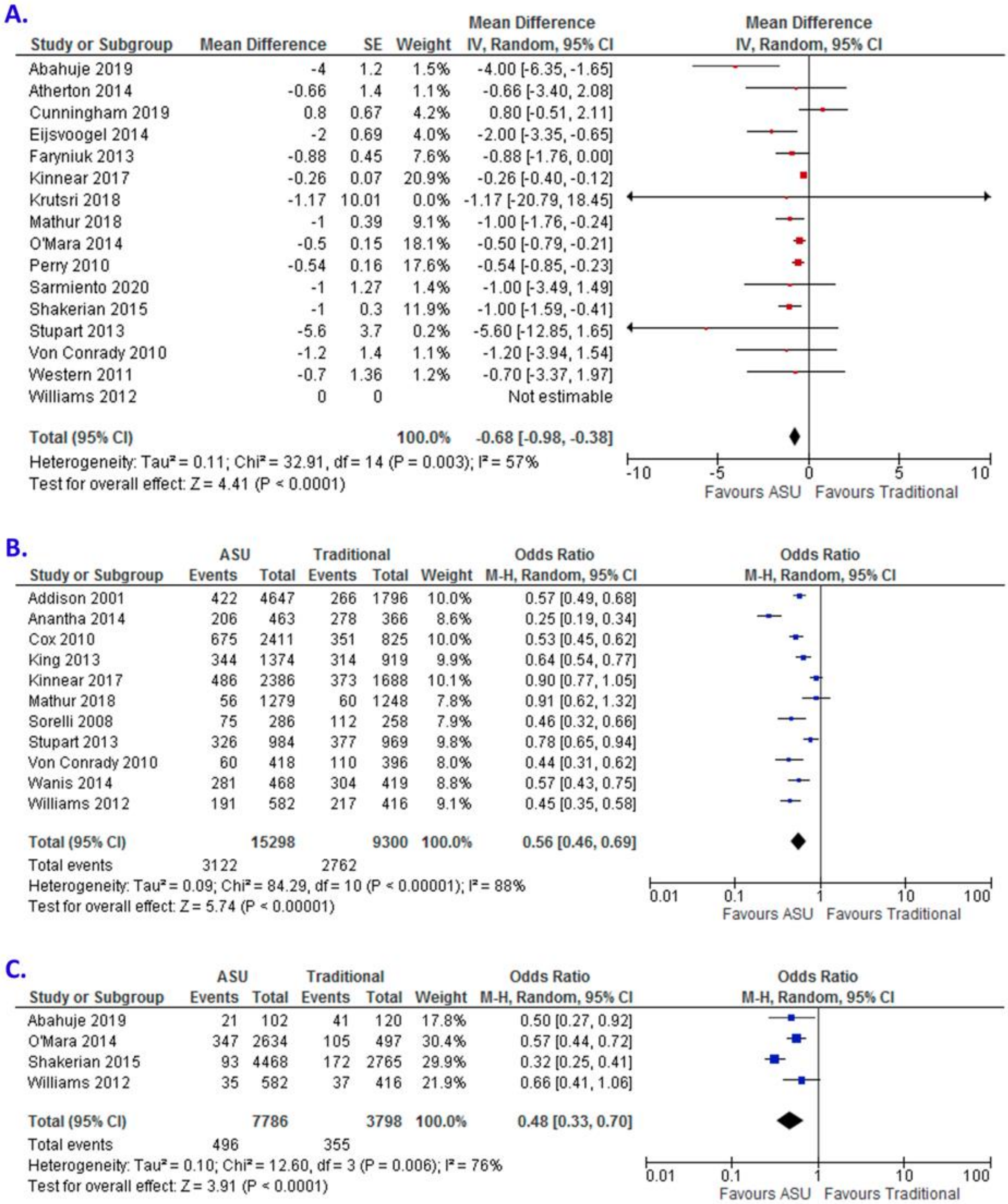
Time to surgical review

Time to surgical review was reported in six cohorts of patients with any diagnosis, representing 9,809 patients (41-43, 152, 159). ASU introduction was associated with a mean reduction in time to surgical review of 0.73 hours (95% CI 0.33–1.14, p=0.0004).

Time to theatre

Eight studies totalling 50,906 patients reported time to theatre for patients with any diagnosis (43, 44, 76, 152, 155, 159, 163, 165). ASU commencement was associated with mean reduction in time to theatre of 1.65 hours (95% CI 0.58-2.73, p=0.003).

Figure 2. Meta-analysis forest plots of primary outcomes (A) length of stay, (B) after-hours operating and (C) complications.



Mortality

Inpatient or 30-day mortality rates were reported for 98,396 patients with any diagnosis across nine studies (40, 41, 44, 76, 150, 153, 154, 156, 158). ASU commencement was associated with reduced mortality rates, with odds ratio 0.70 (95% CI 0.53-0.92, p=0.01).

Re-admissions

Rates of re-admission, typically within 30 days, were reported for 20,556 patients with any diagnosis within five studies (41, 154, 156, 158, 159). Introducing an ASU did not affect re-admission rates (odds ratio 1.03, 95% CI 0.85-1.25, p=0.29).

Cholecystectomy on index admission

For patients with acute biliary disease, rates of cholecystectomy on index admission were reported in seven studies (2,306 patients) (51, 120, 125, 127, 134, 139, 160). Establishing an ASU was associated with significantly increased rates of index cholecystectomy, with odds ratio 3.59 (95% CI 2.15-5.97, p<0.00001).

3.3. Publication bias

Publication bias was assessed with funnel plots for all meta-analyses (Appendix 18). While a small number of studies lay outside the triangular region, all plots displayed approximate symmetry, and there was no strong evidence of publication bias.

3.4. Risk of bias

Applying the Newcastle-Ottawa Quality Assessment Scale, most publications were of high (thirteen studies) or intermediate (35 studies) risk of bias. The remaining 29 studies were assessed as low risk of bias (Appendix 19).

4. DISCUSSION

Implementation of the ASU model has been recommended by multiple healthcare bodies, including the Royal College of Surgeons of England and General Surgeons Australia (49, 66). This review supports these recommendations, and presents the strongest evidence to date of the benefits of the ASU model for patients, staff and health budgets. For patients with any emergency general surgical diagnosis, introduction of an ASU was associated with superiority for all primary outcomes, including length of stay, after-hours operating theatre rates, complication rates and cost. It was also associated with improvement in four of five secondary outcomes, namely time to review, time to theatre and mortality for patients with any diagnosis, and cholecystectomy on index admission for patients with biliary disease. The sole unaffected outcome was re-admission rates.

These robust results were further supported by sub-group analyses (*Appendices 4 and 5*). For patients with appendicitis, ASU commencement was associated with reduced length of stay, after-hours operating rates, complications and time to review, while cost, time to theatre, mortality and re-admission rates were unchanged. For patients with biliary disease, in addition to being over three times more likely to receive definitive surgery on their first presentation, ASU introduction was also associated with reduced length of stay, complications, time to review, time to theatre and re-admission rates. After-hours operating rates, cost and mortality rates were unchanged.

Length of stay is a natural marker of health service efficiency. Patients discharged earlier return to their families sooner, and may suffer fewer work days lost. In this review, for patients with any diagnosis ASU introduction was associated with a 0.7 day reduction in length of stay. While some of these gains may be attributable to increased uptake of laparoscopic approaches and early recovery after surgery protocols, the consistency of this finding, overall and within sub-groups, points to a genuine benefit from the ASU model itself. We expect in addition to the aforementioned favourable but nevertheless confounding factors, patients benefit from cumulative small gains associated with an ASU, including reduced time to theatre, and reduced complications.

After-hours operating is associated with increased morbidity and mortality (389) and the Australian Medical Association's National Code of Practice regards it as hazardous (61). A recent survey of 99% of the general surgery departments in medium to large Australian public hospitals found that increased daytime theatre access is the most common desired change amongst surgeons (295). Positively, this review found the ASU model to be associated with a 44% reduction in after-hours operating rates.

The Australian Commission on Safety and Quality in Healthcare admonishes that 'an unacceptable proportion of Autralian hospital admissions are associated with an adverse event' (390).Compared with patients treated within a Traditional structure, overall ASU patients experienced 52% fewer complications. This is perhaps the strongest benefit of the ASU model and forms one of the clearest arguments in its favour.

Regarding cost, four of ten eligible studies found an association between ASU model implementation and significant net savings, while the remaining six were neutral. However, cost benefits are likely to have been under-estimated, as neither complications, length of stay nor work days lost were factored into any included study's financial analysis (Table 2). The diverse international origin of these studies, with their varying funding models, confound the issue. It is likely that the ASU achieves greatest savings in scenarios of low overheads, high patient volume and significant reduction in length of stay, complications and staff overtime hours.

The acute surgical unit model has been systematically reviewed previously. Existing reviews by first authors Nagaraja, Page, Chana, Murphy, Balasubramanian and Vergis have each enrolled between nine to twenty five studies, and 6,425 to 18,331 patients (58, 211, 212, 249, 375, 391). Several of these works were limited by methodological concerns. Three reviews included multiple papers which did not compare outcomes before and after implemenation of an ASU (211, 249, 391). When comparing published reviews with the original papers included, inaccurate data collection was prevalent, which influenced subsequent analyses and conclusions (191, 211, 212, 249). Furthermore, three reviews assessed neither their included studies' quality nor risk of publication bias (58, 212, 249). Subsequently, this updated analysis represents the largest and most exhaustive collation of literature on the ASU model. With broad inclusion criteria, 77 studies were identified, representing >150,000 patients.

Using the World Bank's definitions, there was only a single identified instance of the ASU model occurring in a low or lower-middle income country (USD <$4,095 gross national income per capita per annum) (392). This occurred in the University

Teaching Hospital of Kigali, Rwanda, where Abahuje *et al*. reported the establishment of an ASU was associated with reduced length of stay (44). Although extrapolations are difficult from this single retrospective study, the authors hypothesise that the establishment of future acute surgical units in low-income settings will be associated with superior outcomes.

This review's principal limitations are the heterogeneity of included studies' ASU structures and outcome definitions (Table 2). While no obvious publication bias was identified, most studies were of poor or intermediate quality. All included works were non-randomised. This is unsurprising, as randomisation to simultaneous structures, each requiring staffing with pools of surgeons and often dedicated operating theatres, would be prohibitively resource-intensive. However, potential biases are likely to be greater for non-randomised studies, so results should be interpreted with caution. Additionally, regarding systematic searches for grey literature beyond bibliographies, the methodological decision to review conference proceedings from only the annual scientific conventions of the Royal Australasian College of Surgeons may have omitted comparable abstracts from other regions. The authors believe this has not impacted study findings, as 22 cohorts were included from conference proceedings, of which only seven were from Australia.

Conclusion

The ASU model is superior or equivalent to the Traditional model for all measured metrics, including reduced length of stay, after-hours operating rates, complications and cost. ASU introduction should be promoted in health policy for the benefit of patients, staff and health budgets.

TABLES

Table 1. Demographics and reported outcomes of eligible cohorts.

Year	First author	Site	Nation	Type	Cohort details	MA group	Trad N	ASU N	Trad period (mo)	ASU period (mo)	TTR	TTT	LOS	A/h OT	Comp.	Mort.	IC	Re-admit	Cost		
																			Savings (USD)	SE	p-value
2001	Addison (3)	Royal Infirmary Edinburgh	UK	Article	EGS admits ± OT	All	2512	5402	12	12				†							
2006	Earley (179)	Hosp. Univ. Pennsylvania	USA	Article	Appendicitis + OT	Appx	127	167	36	36	†	†	†	†	†						
2007	Maa (180)	Univ. of California MC	USA	Article ‡	Appendicitis + OT	Appx	30	30	6	6		†									
2008	Ekeh (378)	Miami Valley Hosp.	USA	Article	Appendicitis + OT	Appx	273	279	15	15		†									
2008	Sorelli (164)	Charing Cross Hosp.	UK	Article	EGS admits ± OT	All	798	824	9	9				†							
2009	Agrawal (209)	Univ. Hosp. NS	UK	Article	Cholecx + OT	Cholecx	45	118	20	8		†	†		†	†					
2009	Shackleton (120)	John Hunter	Australia	Conf.	Colic/ Cholecx ± OT	Cholecx	45	70	6	6		†	†	†			†				
2010	Britt (379)	Sentara Norfolk GH	USA	Article	Cholecx + OT	Cholecx	54	132	12	24		†	†		†						
2010	Cox (166)	Nepean Hosp.	Australia	Article	EGS admits + OT	All	825	1200	12	12				†							
2010	Gandy (191)	Prince of Wales Hosp.	Australia	Article	Appendicitis + OT	Appx	176	226	12	12		†	†	†	†						
2010	Lapierre (177)	Ottawa Hosp.	Canada	Conf.	Cholecx admits ± OT	Cholecx	54	69	19	17			†								
2010	Lehane (121)	Prince of Wales Hosp.	Australia	Article	Cholecx + OT	Cholecx	87	115	24	24		†	†		†						
2010	Milzman (183)	Washington	USA	Conf.	Appendicitis + OT	Appx	60	60	18	18		†	†		†						
2010	Perry (102)	Christchurch Hosp.	NZL	Article	EGS admits ± OT	All	5346	3836	14	10			†								
2010	Von Conrady (157)	Fremantle Hosp.	Australia	Article ‡	EGS admits ± OT	All	688	771	3	3	†		†	†							
2011	Lau (132)	Kaiser Permanente MC	USA	Article	Cholecx + OT	Cholecx	81	71	12	12		†	†	†	†	†					
2011	Qureshi (380)	Sunnybrook HSc Centre	Canada	Article	Appx admits ± OT	Appx	177	137	18	12		†	†				†				
2011	Western (156)	Royal Cornwall Hosp.	UK	Article ‡	EGS admits ± OT	All	5107	5518	12	12			†			†		†			
2012	Cubas (381)	Loma Linda Univ. MC	USA	Article	Appx + OT	Appx	82	93	12	12	†	†	†		†				$1924	$739	0.01
2012	Cubas (381)	Loma Linda Univ. MC	USA	Article	Colic/ Cholecx ± OT	Cholecx	51	62	12	12	†	†	†		†				$3225	$1886	0.09
2012	Hsee (159)	Auckland City Hosp	NZL	Article ‡	EGS admits + OT	All	1200	2613	12	24	†	†						†			
2012	Lee (382)	Nepean Hosp.	Australia	Conf.	Diverticulitis ± OT	Divx	17	43	24	24	†	†	†		†						
2012	Pepingco (160)	Nepean Hosp.	Australia	Article	Cholecx admits ± OT	Cholecx	114	157	24	24		†	†	†	†		†				
2012	Williams (133)	Sunshine Hosp.	Australia	Conf. ‡	EGS admits + OT §	All	416	582	9	18			†	†	†						
2012	Williams (133)	Sunshine Hosp.	Australia	Conf. ‡	Appx + OT	Appx	101	84	9	9		†									
2012	Williams (133)	Sunshine Hosp.	Australia	Conf. ‡	Biliary disease + OT	Cholecx	51	40	9	9		†									
2013	Brockman (193)	Univ. Hosp. Geelong	Australia	Article ‡	Appx + OT	Appx	351	357	12	12			†	†	†	†		†			
2013	Faryniuk (152)	St. Boniface GH	Canada	Article	EGS admits ± OT ||	All	67	142	3	3	†	†	†								
2013	Faryniuk (152)	St. Boniface GH	Canada	Article	Appx admits ± OT	Appx	35	77	3	3		†									
2013	Faryniuk (152)	St. Boniface GH	Canada	Article	Cholecx admits ± OT	Cholecx	5	39	3	3		†									
2013	Faryniuk (152)	St. Boniface GH	Canada	Article	SBO ± OT	SBO	27	26	3	3		†									
2013	King (162)	Wagga Wagga	Australia	Web	EGS admits + OT	All	919	1374	11	13				†							
2013	Lim (130)	Univ. of Alberta Hosp.	Canada	Article	Cholecx + OT	Cholecx	72	172	12	24		†	†	†	†	†		†			
2013	McGlade (134)	Univ. Hosp. Geelong	Australia	LTE	Cholecx admits ± OT	Cholecx	373	130	36	12		†		†			†				
2013	McGlade (134)	Univ. Hosp. Geelong	Australia	LTE	GS pancreatitis ± OT	GS panc	91	38	36	12							†				
2013	Pillai (204)	Auckland City Hosp	NZL	Article	Appx + OT	Appx	875	982	29	31		†	†	†	†	†		†			
2013	Poh (194)	Monash MC	Australia	Article	Appx + OT	Appx	256	283	12	12		†	†	†	†						
2013	Stupart (155)	Univ. Hosp. Geelong	Australia	Article ‡	EGS admits + OT	All	966	984	11	11		†	†	†							
2013	Stupart (155)	Univ. Hosp. Geelong	Australia	Article ‡	Colic/ Cholecx + OT	Cholecx	96	101	11	11			†								
2013	Stupart (155)	Univ. Hosp. Geelong	Australia	Article ‡	Laparotomy + OT	Laparot.	160	144	11	11		†	†								
2014	Anantha (161)	Victoria Hosp.	Canada	Article	EGS admits + OT	All	366	463	6	6				†					$148	$50	0.003
2014	Anantha (383)	Victoria Hosp.	Canada	Article	EGS + CR	CR	47	37	36	24		†	†				†				
2014	Atherton (150)	Univ. Hosp. Aintree	UK	Conf. ‡	EGS admits ± OT	All	17487	13979	48	36			†			†					
2014	Atherton (150)	Univ. Hosp. Aintree	UK	Conf. ‡	Laparotomy + OT	Laparot.	421	644	24	36						†					
2014	Ball (384)	Alberta HS	Canada	Article	Appx referrals ± OT	Appx	349	392	3	3		†									
2014	Beardsley (195)	Canberra Hosp.	Australia	Article	Appx + OT	Appx	84	66	3	3	†	†		†							
2014	Capizzani (184)	Cleveland Clinic	USA	Conf.	Appx + OT	Appx	81	84	18	24			†			†					
2014	Capizzani (184)	Cleveland Clinic	USA	Conf.	Cholecx + OT	Cholecx	97	38	18	24			†			†					
2014	Capizzani (184)	Cleveland Clinic	USA	Conf.	EGS + CR	CR	107	78	18	24			†			†					
2014	Eijsvoogel (158)	Academic MC	NED	Article	EGS admits ± OT	All	211	249	2	2			†			†		†			
2014	Fu (189)	Taipei Univ. Hosp.	Taiwan	Article	Appx + OT	Appx	146	159	12	12		†	†	†	†			†			
2014	Krouchev (385)	L'Enfant-Jesus Hosp.	USA	Conf. ‡	Appx + OT	Appx	85	84	9	9	†	†	†								
2014	Lancashire (196)	Gold Coast Hosp.	Australia	Article	Appx + OT	Appx	247	301	12	12	†	†	†	†	†	†			-$23	$385	0.95
2014	Lien (197)	Prince of Wales Hosp.	Australia	Article	SBO ± OT	SBO	50	171	n/s	66		†	†		†	†					
2014	Michailidou (386)	Univ. of Arizona MC	USA	Article	Cholecx + OT	Cholecx	94	234	12	12		†	†	†	†			†	$976	$496	0.05
2014	O'Mara (154)	Sutter MC Sacramento	USA	Article	EGS admits + OT	All	497	2634	12	48			†		†	†		†	$2513	n/s	<0.001
2014	O'Mara (154)	Sutter MC Sacramento	USA	Article	Appx + OT	Appx	196	882	12	48			†		†	†		†	$2865	n/s	<0.001
2014	O'Mara (154)	Sutter MC Sacramento	USA	Article	Cholecx + OT	Cholecx	178	842	12	48			†		†	†		†	$2279	n/s	<0.001
2014	Sreeramoju (185)	Cedars-Sinai MC	USA	Conf.	Colic/ Cholecx + OT	Cholecx	181	330	24	24			†		†						
2014	Suen (198)	Royal Melbourne Hosp.	Australia	Article	Appx + OT	Appx	276	399	24	24		†	†	†							
2014	Wanis (165)	St. Paul's Hosp.	Canada	Article	EGS admits + OT ||	All	419	468	12	12		†		†							
2014	Wanis (165)	St. Paul's Hosp.	Canada	Article	Appx + OT	Appx	142	150	12	12			†								
2014	Wanis (165)	St. Paul's Hosp.	Canada	Article	Cholecx + OT	Cholecx	55	70	12	12			†								
2014	Wanis (165)	St. Paul's Hosp.	Canada	Article	SBO + OT	SBO	89	74	12	12			†								
2014	Wright (186)	Michigan State Univ. MC	USA	Article	Appx + OT	Appx	526	345	18	12		†	†	†	†			†			
2015	Shakerian (40)	Royal Melbourne Hosp.	Australia	Article	EGS admits ± OT	All	2765	4468	24	24			†		†	†					
2015	Shakerian (40)	Royal Melbourne Hosp.	Australia	Article	Laparotomy + OT	Laparot.	314	226	24	24						†					
2015	Shakerian (125)	Royal Melbourne Hosp.	Australia	Article	Biliary disease ± OT ¶	Cholecx	254	312	24	24		†	†		†	†	†				
2015	Suhardja (126)	Monash MC	Australia	Article	Colic/ Cholecx + OT	Cholecx	179	163	12	12		†	†	†	†						
2015	Suhardja (126)	Monash MC	Australia	Article	GS pancreatitis + OT	GS panc	16	28	12	12		†	†	†	†						
2016	Bokhari (127)	Northwick Park Hosp.	UK	Article	Cholecx admits ± OT	Cholecx	126	152	12	12			†		†			†	-$712	$804	n/s
2016	Musiienko (199)	Royal Melbourne Hosp.	Australia	Article	SBO ± OT	SBO	225	256	24	24			†	†	†	†		†			
2016	Song (131)	Myongji Hosp.	KOR	Article	Cholecx + OT	Cholecx	62	62	n/s	n/s		†	†	†	†	†		†			
2017	Allaway (200)	Nepean Hosp.	Australia	Article	Appx + OT	Appx	277	553	24	24		†	†	†	†						
2017	Davis (135)	Wake Forest Baptist MC	USA	Article	Cholecx + OT	Cholecx	88	84	36	36		†	†		†	†					
2017	Farrell (187)	Christiana Care HSv	USA	Article ‡	Appx + OT	Appx	1602	1652	54	50		†	†		†						
2017	Kinnear (163)	Lyell McEwin HS	Australia	Article ‡	EGS admits + OT	All	1688	2386	30	30		†	†	†		†					
2017	Martin (387)	Royal Victoria Hosp.	UK	Conf. ‡	Appx + OT	Appx	257	272	n/s	n/s		†	†	†	†						
2017	Murphy (178)	London HSc Centre	Canada	Article	GS pancreatitis ± OT	GS panc	139	55	36	12		†	†	†			†		$6765	$41	<0.001
2017	Pritchard (128)	Bendigo Health	Australia	Article	Appx + OT	Appx	421	380	24	24		†	†	†							
2017	Pritchard (128)	Bendigo Health	Australia	Article	Cholecx + OT	Cholecx	149	235	24	24		†	†	†	†						
2017	Yahya (201)	Eastern Health	Australia	Conf. ‡	Appx admits ± OT	Appx	256	300	18	18		†	†	†							
2017	Yahya (201)	Eastern Health	Australia	Conf. ‡	Cholecx admits ± OT	Cholecx	74	116	18	18		†	†	†							
2018	Al-Omaishi (136)	Ochsner MC	USA	Conf. ‡	Cholecx + OT	Cholecx	65	140	n/s	n/s		†	†		†	†		†			
2018	Bazzi (51)	Lyell McEwin HS	Australia	Article ‡	Cholecx admits ± OT	Cholecx	172	147	24	24	†	†	†	†	†		†				
2018	Dickfos (42)	Prince Charles Hosp	Australia	Article ‡	EGS referrals ± OT	All	332	376	6	6	†										

2018	Guy (388)	Logan Hosp.	Australia	Article	Laparotomy + OT	Laparot.	58	109	12	12	†	†	†	†	†	†		†			
2018	Krutsri (43)	Ramathibodi Hosp.	Thailand	Article	EGS admits ± OT	All	359	734	12	12	†	†	†								
2018	Krutsri (43)	Ramathibodi Hosp.	Thailand	Article	Appx admits ± OT	Appx	204	200	12	12	†	†	†								
2018	Krutsri (43)	Ramathibodi Hosp.	Thailand	Article	Cholecx admits ± OT	Cholecx	53	40	12	12	†	†	†								
2018	Krutsri (43)	Ramathibodi Hosp.	Thailand	Article	SBO admits ± OT ††	SBO	77	78	12	12	†	†	†								
2018	Mathur (41)	Khoo Teck Puat Hosp.	Singapore	Article	EGS admits ± OT	All	1248	1279	6	6	†	†	†	†		†		†	$359	$198	0.07
2018	Mathur (41)	Khoo Teck Puat Hosp.	Singapore	Article	Appx admits ± OT	Appx	176	188	6	6	†	†	†						$244	$165	0.14
2018	Mathur (41)	Khoo Teck Puat Hosp.	Singapore	Article	Cholecx admits ± OT	Cholecx	41	28	6	6	†	†	†						$673	$171	0.24
2018	McGrath (205)	Cork Univ. Hosp.	Ireland	Conf.	Appx + OT	Appx	129	177	4	5		†	†	†	†						
2019	Abahuje (44)	Hosp. Univ. de Kigali	Rwanda	Article	EGS admits + OT	All	120	102	3	3		†	†		†	†					
2019	Cralley (137)	Denver Health MC	USA	Conf.	Cholecx + OT	Cholecx	168	161	6	6		†	†								
2019	Cunningham (151)	UT Southwestern MC	USA	Conf.	EGS admits ± OT	All	505	1135	12	24			†								
2019	Hx (188)	Khoo Teck Puat Hosp.	Singapore	Conf.	Appx + OT	Appx	192	179	6	6				†	†						
2019	Kinnear (153)	LMHS	Australia	Article ‡	Appx + OT	Appx	465	749	30	30		†	†	†	†	†					
2019	Luo (138)	Northern Health	Australia	Article	Cholecx + OT	Cholecx	282	305	12	12		†	†	†	†	†		†			
2020	Goh (139)	Khoo Teck Puat Hosp.	Singapore	Article	Cholecx admits ± OT	Cholecx	82	172	12	12		†	†	†	†		†	†			
2020	Sarmiento (76)	Vicente Corral Moscoso	Ecuador	Article	EGS admits + OT	All	15677	22981	60	60		†	†			†					

Admits: admissions. Appx: appendicitis. ASU: acute surgical unit model. A/h OT: after hours operating theatre rates. Cholecx: cholecystitis. Colic: biliary colic. Comp.: complication rates. Conf.: conference proceedings. CR: colonic resection. EGS: emergency general surgery. GS: gallstone. GH: general hospital. HS: health system/ service(s). HSc: Health sciences. Hosp.: hospital. IC: rates of cholecystectomy on index admission. KOR: South Korea. Laparot.: laparotomy. LOS: length of stay. LTE: letter to editor. MA: meta-analysis. MC: medical centre. Mo: months. Mort.: mortality rates. N: number of patients. NED: The Netherlands. NS: North Staffordshire. NZ: New Zealand. N/s: not stateed. OT: operating theatre. Re-admit: re-admission rates. SBO: small bowel obstruction. Trad: traditional model. TTR: time to surgical review. TTT: time to theatre. UK: United Kingdowm. Univ.: university. USA: United States of America. +: with. ±: with or without. †: outcome reported in this cohort. ‡: correspondence with author(s). §: appendicitis, right iliac fossa pain for investigation or biliary disease. ||: appendicitis, cholecystitis or small bowel obstruction. ¶: biliary colic, cholecystitis, choledocholithiasis, cholangitis. ††: includes large bowel obstruction.

Table 2. Variations in study definitions for selected outcomes.

Year	First author	Nation	TTR	TTT	LOS	After hours	Complications	Mort.	Re-admit	Costing method
2001	Addison (3)	UK				0000 - 0800				
2006	Earley (179)	USA	Triage – surg rv	Surg rv – in OT room	mean	1600 - 0800	Selected ‡			
2007	Maa (180)	USA		Triage – skin incision						
2008	Ekeh (378)	USA		Triage – skin incision						
2008	Sorelli (164)	UK				1700 - 0800				
2009	Agrawal (209)	UK		Admit – ‘OT’ unclear	median		Unclear			
2009	Shackleton (120)	Australia		Admit – ‘OT’ unclear	mean	1700 - 0800				
2010	Britt (379)	USA		Surg rv – ‘OT’ unclear	mean		Any	Inpt.		
2010	Cox (166)	Australia				1800 - 0800				
2010	Gandy (191)	Australia		Triage – in OT room	median	1700 - 0800	Any			
2010	Lapierre (177)	Canada			mean					
2010	Lehane (121)	Australia		Surg rv – ‘OT’ unclear	median		Any			
2010	Milzman (183)	USA		Surg rv – ‘OT’ unclear	mean		WI, ileus, SBO			
2010	Perry (102)	NZL			median					
2010	Von Conrady (157)	Australia	Refer – surg rv		mean	1800 - 0700				
2011	Lau (132)	USA		Triage – in OT room	mean	2000 - 0700	Any	Inpt.		
2011	Qureshi (380)	Canada		Surg rv – ‘OT’ unclear	mean					
2011	Western (156)	UK			mean			Inpt.	Unclear	
2012	Cubas (381)	USA	triage – surg rv	Triage – in OT room	mean		Any			‘Crimson SQL query’
2012	Hsee (159)	NZL	Refer – surg rv	OT booking – in OT room					28 day	
2012	Lee (382)	Australia	Unclear	Unclear	mean		WI			
2012	Pepingco (160)	Australia		Unclear	mean	1700 - 0800	WI, CBD injury or jaundice			
2012	Williams (133)	Australia		Imaging – skin incision	median	1730 - 0800	Clavien III only			
2013	Brockman (193)	Australia			mean	0000 - 0800	WI, collection or MI	Inpt.	Unclear	
2013	Faryniuk (152)	Canada	Refer – surg rv	Surg rv – ‘OT’ unclear	mean					
2013	King (162)	Australia				1800 – 0800				
2013	Lim (130)	Canada		Admit – ‘OT’ unclear	mean	Unclear	Any	Inpt.	Unclear	
2013	McGlade (134)	Australia		Triage – ‘OT’ unclear		Unclear				
2013	Pillai (204)	NZL		OT booking – skin incision	mean	1630 – 0730	WI, collection	Inpt.	30 day	
2013	Poh (194)	Australia		Refer – skin incision	median	1800 – 0800	WI			
2013	Stupart (155)	Australia		OT booking – ‘OT’ unclear	mean	1800 - 0800				
2014	Anantha (161)	Canada				1500 - 0700				OT billings + a/h premiums
2014	Anantha (383)	Canada		Admit – ‘OT’ unclear	median					
2014	Atherton (150)	UK			mean			30 day		
2014	Ball (384)	Canada		Triage – ‘OT’ unclear						
2014	Beardsley (195)	Australia	ED MO rv – surg rv	Triage – skin incision		1800 - 0700				
2014	Capizzani (184)	USA			median			Inpt.		
2014	Eijsvoogel (158)	NED			median			30 day	30 day	
2014	Fu (189)	Taiwan		Triage – ‘OT’ unclear	mean	1700 - 0800	Unclear		14 day	
2014	Krouchev (385)	USA	Unclear	Unclear	mean					
2014	Lancashire (196)	Australia	Triage - admission	Triage – skin incision	mean	1800 - 0730	Any	Inpt.		Unclear
2014	Lien (197)	Australia		Surg rv – in OT room	median		Any	Inpt.		
2014	Michailidou (386)	USA		Triage – in OT room	mean	0000 - 0700	Any		Unclear	‘hospital accounting system’
2014	O'Mara (154)	USA			mean		Any	Inpt.	Unclear	‘hospital financial office’
2014	Sreeramoju (185)	USA			median		Unclear			
2014	Suen (198)	Australia		Admit – in OT room	median	1700 – 0800				
2014	Wanis (165)	Canada		OT booking – ‘OT’ unclear	mean	1600 – 0800				
2014	Wright (186)	USA		Surg rv – in OT room	mean	1900 – 0700	Unclear		30 day	
2015	Shakerian (40)	Australia			median		Any	Inpt.		
2015	Shakerian (125)	Australia		Unclear	median		Any	Inpt.		
2015	Suhardja (126)	Australia		Triage – ‘OT’ unclear	median	1800 - 0800	WI, CBD leak or injury			
2016	Bokhari (127)	UK			mean		Any		Unclear	‘trust finance manager’
2016	Musiienko (199)	Australia			median	1700 - 0800	Unclear	Inpt.	30 day	
2016	Song (131)	KOR		Unclear	mean	1800 - 0700	Unclear	Inpt.	Unclear	
2017	Allaway (200)	Australia		Triage – ‘OT’ unclear	mean	1900 - 0700	Any			
2017	Davis (135)	USA		Imaging – skin incision	mean		Selected §	30 day		
2017	Farrell (187)	USA		OT booking – in OT room	mean		All			
2017	Kinnear (163)	Australia		Refer – skin incision	mean	1800 – 0800		Inpt.		
2017	Martin (387)	UK		Triage – skin incision	mean	Unclear	WI, intervention ||			
2017	Murphy (178)	Canada		Triage – ‘OT’ unclear	median	1700 – 0700				‘Ontario case costing program’
2017	Pritchard (128)	Australia		Admit – skin incision	median	1800 – 0800				
2017	Yahya (201)	Australia		Unclear	median	1800 – 0800				
2018	Al-Omaishi (136)	USA		Admit – in OT room	mean		Unclear	Inpt.	30 day	
2018	Bazzi (51)	Australia	Triage - admission	Imaging – skin incision	mean	1700 - 0800	Any			
2018	Dickfos (42)	Australia	Refer – surg rv							
2018	Guy (388)	Australia	Unclear	Refer – ‘OT’ unclear	median	1700 - 0800	Any	30 day	Unclear	
2018	Krutsri (43)	Thailand	Refer – surg rv	OT booking – in OT room	median					
2018	Mathur (41)	Singapore	Refer – surg rv	OT booking – ‘OT’ unclear	mean	1600 - 0730		Inpt.	30 day	Hospital bill
2018	McGrath (205)	Ireland		Admit – ‘OT’ unclear	mean	Unclear	Unclear			
2019	Abahuje (44)	Rwanda		Admit – ‘OT’ unclear	median		Any	Inpt.		
2019	Cralley (137)	USA		Admit – ‘OT’ unclear	mean					
2019	Cunningham (151)	USA			mean					
2019	Hx (188)	Singapore				1600 - 0730	Any			
2019	Kinnear (153)	Australia		Refer – skin incision	mean	1800 – 0800	Any	Inpt.		
2019	Luo (138)	Australia		Imaging – skin incision	median	1700 – 0800	Any	Inpt.	90 day	
2020	Goh (139)	Singapore		OT booking – ‘OT’ unclear	mean	1700 - 0730	WI, collection, organ injury		30 day	
2020	Sarmiento (76)	Ecuador		Triage – in OT rom	median			Inpt.		

Admit: admission. AUR: acute urinary retention. A/h OT: after hours operating. CBD: common bile duct. Comp.: complications. IC: cholecystectomy on index admission. Inpt.: inpatient. KOR: South Korea. LOS: length of stay. MI: myocardial infarction. Mort.: mortality. NED: The Netherlands. NZL: New Zealand. OT: operating theatre. Refer: ED referral to general surgery. Re-admit: re-admissions. Rv: review. SBO: small bowel obstruction. SE: standard error. TTR: time to surgical review. TTT: time to theatre. UK: United Kingdom. USA: United States of America. USD: United States dollars, converted from currency of study on date of publication.

WI: wound infection. †: per patient savings associated with introduction of an acute surgical unit model. ‡: WI, ileus, SBO, haemorrhage, AUR. §: WI, CBD leak or injury, bowel injury, haemorhage. ||: radiological or surgical.

Chapter 10: Discussion and Conclusions

This body of research has concerned itself with optimising allocation of resources to care for both elective and EGS patients. The ASU model co-prioritises staff and theatre time for both cohorts, rather than the Traditional supremacy of elective patients with their EGS counterparts being managed ad-hoc. Despite many prior studies finding ASU introduction to be associated with superior outcomes, uptake remains slow, in part due to lingering uncertainty regarding benefits. Hence, in the introductory section 'The Problem', three objectives for this thesis were proposed; *'[1] addressing key gaps in the ASU literature, [2] providing guidance for both national policymakers and hospitals considering implementing an ASU, and [3] defining future areas of research*'. Having addressed the thesis objectives, we will then discuss four final topics. These are [4] further Traditional and ASU model pros and cons, [5] guidance for general surgical departments considering establishing an ASU, [6] further measures to improve EGS services and [7] thesis limitations.

10.1. Summarising the results

This thesis has examined the ASU model on a varied scale, with studies of local, national and global scope. It has also employed diverse methodology, including retrospective and prospective studies, single and multi-centre enrolment and systematic review. Subsequently, a wealth of evidence reveals that compared with the Traditional structure, the ASU model is associated with superior outcomes. These are reliably and repeatedly observed in a wide range of settings, and for multiple different stakeholders.

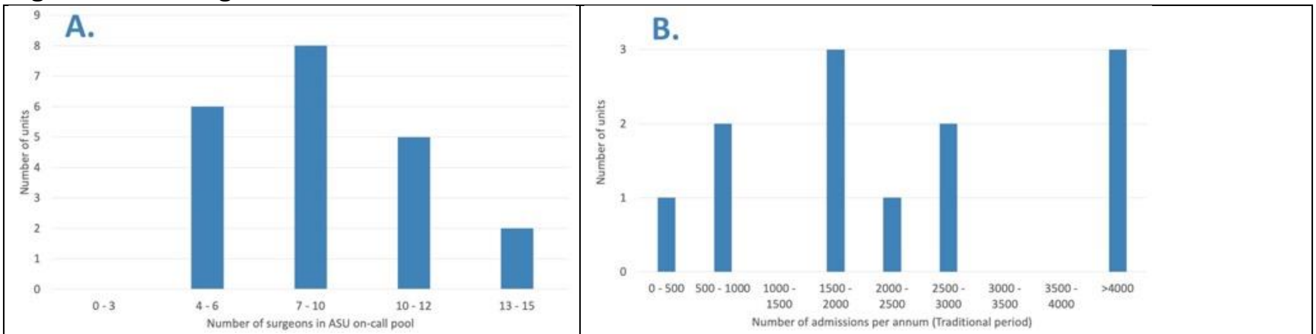
- For patients, on a local scale, those with appendicitis (publication one) or cholecystitis (publication three) both suffer fewer complications. The latter group also enjoy shorter length of hospital stay and higher rates of definitive surgery on first admission. On a global scale, patients with any EGS diagnosis experience reductions in complications, deaths and length of stay (publication eight). There appears to also be an emerging role for the ASU model in other surgical specialties (publication seven).
- For staff, on a national scale, the majority of Australian medium- to major-sized public hospitals have moved from the Traditional to an ASU or Hybrid model (publication five). For both registrars and consultants, working within these latter structures is associated with shorter maximum periods on-duty and greater satisfaction (publication six). Evidence from studies with local, national or global scope all find ASU implementation to be associated with reduced after-hours operating (publications one, three, four and eight).
- For health budgets, compared with the Traditional unit, commencing an ASU has globally been associated with financial equivalence or costs savings (publication eight). Importantly, while there were several instances where EGS model made no difference (publication two), amongst these eight studies not a single outcome was significantly in favour of the Traditional model.

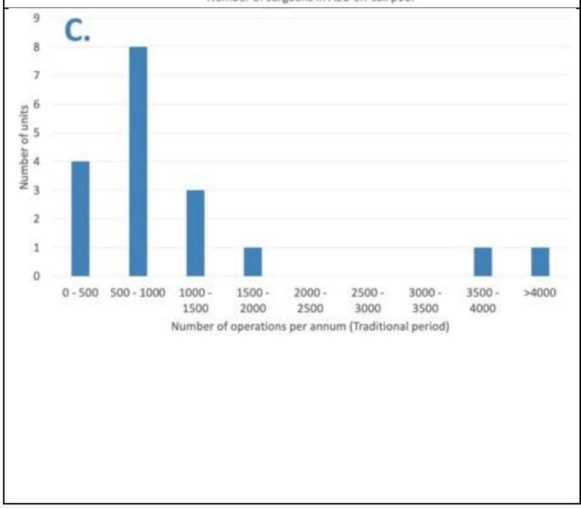
10.2. Health policy guidance

Secondly, based on this work, we suggest the following core recommendations be incorporated into formal policies of the Royal Australasian College of Surgeons and General Surgeons Australia. These will be expanded thereafter.

- The ASU model to represent standard of care for all general surgical departments who meet all criteria of four or more general surgeons, >1,000 EGS admissions per annum and >500 EGS procedures per annum (Figure 1).
- General surgical departments to increase remuneration for EGS on-call, in concert with introducing contractual obligation to provide EGS on-call for new public general surgeon appointments.
- Creation of structured state-wide hospital tiers and inter-hospital transfer mechanisms for EGS patients.

Figure 1. Relationship between number published acute surgical units and (A) number of surgeons in on-call pool, number of emergency general surgery (B) admissions per annum regardless of diagnosis and (C) procedures per annum regardless of diagnosis.





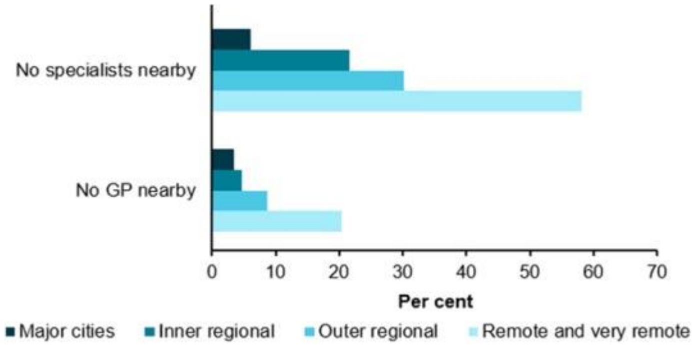
A			B			C		
Year	First author	Surgeons (ASU)	Year	First author	Admits p.a. (Trad)	Year	First author	Procedures p.a. (Trad)
2010	Von Conrady(157)	4	2018	Krutsri (43)	359	2014	O'Mara (154)	124
2020	Sarmiento (76)	4	2019	Cunningham(151)	505	2018	Krutsri (43)	317
2016	Song (131)	5	2018	Dickfos (42)	664	2008	Sorelli (164)	344
2019	Panagiotopoulou (393)	5	2008	Sorelli (164)	1064	2019	Abahuje (44)	480
2001	Addison (3)	6	2014	Eijsvoogel (158)	1266	2014	Eijsvoogel (158)	552
2014	O'Mara (154)	6	2015	Shakerian (40)	1383	2012	Williams (133)	555
2014	Michailidou(386)	7	2018	Mathur (41)	2496	2012	Hsee (159)	600
2010	Gandy (191)	8	2001	Addison (3)	2512	2015	Shakerian (40)	640
2013	King (162)	8	2010	Von Conrady(157)	2752	2017	Kinnear (163)	675
2014	Anantha (161)	8	2014	Atherton (150)	4372	2014	Anantha (161)	732
2014	Wanis (165)	8	2010	Perry (102)	4583	2010	Cox (166)	825
2014	Wright (186)	8	2011	Western (156)	5107	2013	King (162)	848
2017	Murphy (178)	8				2013	Stupart (155)	1054
2013	Lim (130)	9				2018	Mathur (41)	1136
2009	Agrawal (209)	10				2010	Perry (102)	1455
2011	Western (156)	10				2010	Von Conrady(157)	1584
2011	Qureshi (380)	11				2020	Sarmiento (76)	3920
2015	Suhardja (126)	12				2001	Addison (3)	4150
2017	Kinnear (163)	12						
2019	Luo (138)	14						
2013	Stupart (155)	15						

Inset table in bottom right presents data in descending size order.
ASU: acute surgical unit. P.a.: per annum. Trad: traditional unit.

It is clear that establishing an ASU improves outcomes for patients, staff and budgets. However, intuitively it is equally apparent that not all centres are appropriate for this model. A minimum size threshold will exist. Departments with a small number of general surgeons will lose too great a proportion of their elective workforce if one consultant is allocated each day solely to EGS patients. Similarly, hospitals with relatively few EGS admissions or procedures per year do not require a surgeon dedicated to their needs alone. So how big is big enough? The purest answer would come from mathematical modelling, either theoretical or based on real-world single centre figures. Despite a wealth of studies focused on the economics of operating theatre allocation for emergency or elective use (1), such a study does not exist for the overarching question of Traditional versus ASU structure. We are guided then by the size distribution of existing ASUs (Figure 1). Regarding studies which reported the total number of surgeons in the on-call roster, we see that there is not a single example of an operational ASU with fewer than four general surgeons in the on-call roster. All examples of ASUs run by <4 surgeons do so only Monday to Friday in business hours, and after-hours remain supported by a larger pool of surgeons or final year trainees (44, 117, 127, 202, 204). Minimums for EGS patient volume are less explicit. However, approximating a bell-shaped curve to these distributions suggests that only a quarter or fewer of the published ASUs experience <1000 admissions or <500 procedures per annum. Critics may argue the null hypothesis (unit size does affect the impact of ASU commencement) or that the observed distributions suffer sampling error. However, the critical importance of the size of surgeon pool and EGS patient load is supported by both the wealth of studies which describe their impetus for change being the sheer volume of EGS patients (3, 49, 73, 319), and comments from surgeons canvassed across Australia in publication five, such as '*ASU not considered, we're too small*', '*can't justify just standing around for emergencies*' and '*bean counters won't pay for a surgeon doing nothing'*.

Next, general surgery as a profession must move towards a future where all publicly appointed surgeons can perform EGS on-call. Otherwise, given the option an increasing proportion will pursue solely sub-specialised elective practice, leaving a ballooning EGS patient load to a shrinking on-call staff pool. This stance has already been articulated by General Surgery Australia's '*12 Point Plan for Emergency General Surgery*', whose very first point states '*Emergency general surgery is a continuing core competency of a general surgeon*' (66). However, mandating this decree is left to each public hospital. In Australia in 2003, only 83% of general surgeons participated in on-call (4). Anecdotal evidence suggests gradual further retreat from emergency rosters. The authors suggest therefore that when offering new public consultant appointments, general surgical departments both increase funding for EGS duties and establish contractual obligation to deliver EGS care. This approach is supported by Professor Ian Gough, who in 2008 whilst president of the Royal Australasian College of Surgeons recommended '*hospitals should value their surgeons and provide appropriate incentives and conditions of service, including adequate remuneration... to provide emergency services as a condition of their employment*' (4). Hospitals have several ancillary mechanisms with which to support consultants whilst on-call, including protecting time off-call, and rostering a second on-call consultant to provide support and mentorship. This 'back-up' surgeon model is in successful use in several existing ASUs (75, 122, 124, 163, 180, 181, 393).

Figure 2. Experiences in Australian adults aged 45 and over, by remoteness, 2016.



Modified from the Australian Institute of Health and Welfare (394).

Last of the core recommendations is the creation of structured EGS hospital tiers and transfer mechanisms. This has already been flagged in Australian health policy reports; '*[the] networking model ... is considered a key concept for the sustainability of rural surgical practice with ... a regional resource centre that networks with surrounding district hospitals*' (395). Approximately seven million Australians (28% of the population) live outside major cities, and generally reporting higher levels of life satisfaction and community cohesion (394). Concerningly, compared with their urban counterparts, regional and remote citizens suffer higher all-cause mortality (394). One leading explanation relates to comorbidities. They are older, poorer and have higher rates of smoking, alcohol abuse, obesity and diabetes (396, 397). Another is more limited access to Medicare funded healthcare (Figure 2). This cohort typically reside in population centres of <10,000 persons, while surgeons require an estimated 20,000 – 25,000 inhabitants for financial viability (398-400). Despite this, for surgery the benefits of centralisation remain controversial. For patients and their families, metropolitan services are expensive in time and money, considering the travel time, lost income and escort needs (399). After beneficence, non-maleficence and autonomy, the fourth ethical principle of justice behoves clinicians to strive for equal access, regardless of postcode (401). Minor and selected major surgeries can safely be performed regionally (402). A recent 7-year audit of peri-operative death in Australia and New Zealand suggested equivalent mortality for urban and rural settings (398). However, the appeal of centralisation is strong. Firstly, the audit admitted significant confounding through more comorbid regional patients being screened out. These citizens are routinely directed to urban centres, who have superior rates of peri-operative support such as consultant anaesthetists, intensive care unit and other surgical specialties. Secondly, for more complex procedures there is substantial evidence suggesting an inverse relationship between case-volume and mortality (403, 404). Thirdly, regionalised hub-and-spoke schemes already exist in Australia for many clinical scenarios where prompt transfer to higher volume centres may improve outcomes, including neonates, acute coronary syndrome, stroke and trauma (405-408). Fourthly, moves to strengthen inter-hospital systems are gaining momentum internationally. The Royal College of Surgeons of England recommends '*Increasingly EGS will need to be provided on a networked basis, that is, via an interconnected system of service providers*' (169). In the USA where similar geographical challenges exist, simulations indicate '*regionalizing EGS care to higher-volume, lower-mortality EGS institutions*' would decrease cohort mortality by 10% (409).

10.3. Future research

After first addressing clinical equipoise with a suite of compelling evidence, and secondly providing guidance for policymakers, we turn to the third aim of this thesis; defining future areas of investigation. There are many pressing and fertile areas for scrutiny, detailed below.

- Cost comparison of the two common EGS structures. We direct researchers' attention first to money matters, as hospital reorganisation such as the ASU can only receive support following a robust business case. Methodology could comprise either theoretical modelling or prospective assessment of an actual centre before and after commencing an ASU. Neither approach has been yet performed with adequate rigour, including the impact of complications, lost earnings, medical overtime, nursing overtime (130, 410-412) and elective patient cancellation. Day-of-surgery cancellation due to competing EGS patients is common, occurring in 4 – 29% of elective patients (162, 413, 414). As mentioned earlier, mathematical modelling to optimise operating theatre allocation for both emergency and elective patients has been performed by dozens of studies. However, these have typically had narrow focus, and not considered several of the above items; '*Surprisingly, the cost of cancellation is overlooked in many papers which might give a biased view [in favour of] the results of the flexible [Traditional] policy*' (1). Theoretical models could guide thresholds for number of surgeons or EGS patient load of which the ASU model breaks even. Regarding real world analyses, publication eight identified only three studies which had contrasted financial metrics for the Traditional and ASU models for patients with any diagnosis (Table 1) (41, 161, 415). However, like their theoretical counterparts, these again ignored most of the above items, compiling only EGS patient billings. To date only a single centre has assessed the impact of EGS structure on elective patient cancellation, finding a non-significant trend in favour of the ASU model (162).
- Creation of validated key performance indicators in EGS using the formal Delphi method with panel(s) of experts, followed by hospital-based validation

studies. Like many other domains of medicine, reporting bias plagues the ASU literature. Without agreement on which results matter, authors remain free to self-determine. While we anticipate that most authors prospectively choose primary outcomes and behave rigorously, this scenario opens the door for bad actors to collect a wealth of data and then publish selectively. Acknowledging the importance for unison in reporting, the Donegal Summit in 2017 saw clinicians from seventeen European nations meet to develop key performance indicators for EGS patients (416). Appropriately, their backgrounds were multi-disciplinary and included general surgery, anaesthesia, intensive care, radiology and nursing. However, the summit coordinators acknowledged the need (still unmet) to subsequently move from an open consensus to a formal Delphi approach, and then to validate the selected outcomes. Example targets include patient service delivery (e.g. '90% of patients with acute cholecystitis to receive cholecystectomy on index admission'), staff supervision (e.g. '90% of emergency laparotomies to have consultant attendance') or budgetary (e.g. '<50% of surgical staff overtime to occur secondary to emergency operating'). This will enable both clinicians to compare the quality of EGS care and allow academics to homogenously report findings.

- Prospective studies of the impact of instituting an ASU. This would be a much needed first. Most hospitals prospectively recording of a large range of patient data points, and this leads many authors to erroneously claim their work is ergo also prospective. The systematic review (publication eight) found no examples of surgeons deciding to commence an ASU, but waiting 12 months to allow prospective enrolment of a Traditional cohort as controls. In all cases the decision to analyse and the selection of outcomes occurs retrospectively for these patients. However, conducting such a study remains eminently possible, given the often slow pace of institutional change, and the frequent instances of having to wait until additional surgeons are employed before starting an ASU (76, 117, 138, 186, 393).

- Much greater understanding is required on the EGS patient perspective. Patient reported outcomes in EGS remain deeply undervalued; publication four remains the only study in this domain in the Southern hemisphere. While surgeons remain expert at the medical and especially procedural needs of their patients, they may be oblivious to other modifiable drivers of patient satisfaction, such as privacy, prompt analgesia, senior clinician involvement and communication. As is already the case in USA and much of Europe, collection of patient reported outcomes should become an embedded routine part of all surgical admissions (305-307). This will empower patients and guide change. Regardless of EGS model, general surgical departments should establish regular audit cycles of assessment, change and then re-measurement.
- Applicability of the ASU model in specialties other than general surgery. Publication seven identified a small variety of structures dedicated to emergency urological patients. Similarly, the Royal Victoria Eye and Ear Hospital Dublin has been so plagued by disruption of planned procedures that it has proposed a business case for '*separating [sic] of elective and emergency surgery*' for these ophthalmologic and otolaryngology patients (417). However, the most obvious examples appear to be vascular surgery and orthopaedics, whose emergency volume exceeds all surgical specialties

except general surgery, and whose challenges in resource allocation appear strikingly similar. Within orthopaedics for example, unplanned admissions and procedures often outnumber those of elective patients (418), and often disrupt elective activities (419). After-hours operating is common, and associated with higher complication rates (420). Unsurprisingly, many authors have trialled protecting resources for these non-elective patients, most commonly orthopaedic emergency operating theatres, which are widespread (1, 419). Decidedly less common are services dedicated to orthopaedic trauma (akin to the ASU model) (421) and orthopaedics observation units co-located in the emergency department (422), analogous to the surgical assessment units occasionally observed in publication five for EGS patients. These structures remain uncommon and represent potentially high-yield territory for both research and improved patient and staff outcomes.

- Finally, the utility of the ASU model in low and low-middle income nations remains unclear. Publication eight found only a single such instance; in Rwanda, Abahuje *et al*. found the structure to reduce length of stay (44). Despite different circumstances, general surgical departments in these countries share similar challenges in allocating resources to elective and emergency patients. The authors hypothesize that ASU or hybrid models may hold benefit in these settings.

Table 1. Number of patients undergoing an emergency procedure in 2007-2017 within hospitals participating in the American College of Surgeons National Surgical Quality Improvement Program.

Surgical specialty	Number of patients	Mortality
General surgery	132,030	12,242 (9.3%)
Vascular surgery	18,139	2,745 (15.1%)
Orthopaedics	13,821	777 (5.6%)
Neurosurgery	4,825	778 (16.1%)
Gynaecology	1,703	27 (1.6%)
Cardiac surgery	1,280	124 (9.7%)
Urology	1,102	68 (6.2%)

Enrols patients in >700 of the USA's 6,090 hospitals (146, 147). Interventional radiology, otolaryngology and plastic & reconstructive surgery patients were excluded, comprising 4,982 patients. Modified from AlSowaiegh *et al*. (148).

10.4. Further Traditional and ASU model pros and cons

Having addressed the thesis objectives, we now move to the final four topics of discussion. The Traditional structure remains an appropriate choice for some centres. Its continued practice is a testament to its strengths. Familiar to all surgeons, it fits any hospital size and provides superior continuity of care, with less patient handover. Importantly, where it is possible for each specialty department to provide parallel on-call, they may deliver finer care for EGS conditions within their field. Examples of superior outcomes by specialty units include upper gastrointestinal surgeons with non-elective cholecystectomy (423), cholecystitis and colorectal surgeons with non-elective colonic resections (424-427). Lastly, intensive care services are often the largest contributor to overall EGS cost (428). However, to date all comparative studies have found no difference in intensive care unit admission rates between Traditional and ASU structures, for cohorts with any diagnosis (40, 44, 163) or specific EGS pathologies (131, 153, 193, 199). However, the Traditional structure has many negatives, as summarised in '*Table 2. Problems with the traditional model*' and evidenced by widespread abandonment.

The ASU model is not without its shortcomings. Patient handover is more common which may fracture care (190). While rosters vary, some require the consultant to be on-call for up to seven days, which may be fatiguing (Appendix 8). Without adequate planning, the requirement for surgeons to spend periods dedicated in business hours solely to EGS patients may be disruptive to private practice (429, 430). There are also reports that for the surgeon the ASU model presents a negative opportunity cost; '*the current rate of remuneration for the ASU is insufficient and does not cover the lost income from other activities, in particular from their private practice'* (166).

However, these drawbacks are more than offset by a raft of positives. The headline advantages of the ASU model have already been abridged in this chapter's opening paragraph *Summarising the results*. Overall patients experience reduced complications, mortality and length of stay. Staff perform less after-hours operating, have shorter maximum durations on-call and enjoy greater satisfaction. Costings are equivalent or superior. Yet there are still many more important benefits.

For EGS patients, the above outcomes are likely to lead to secondary gains including reduced suffering, additional treatments, time away from family and lost income. Patients with cholecystitis are less likely to represent with their condition still untreated. Also, they may be likely to receive the standard-of-care intra-operative cholangiogram, as radiographers rostered after-hours are often not qualified in this imaging. For elective patients, one of the aims of the ASU model was to reduce cancellations through separating resources for them and EGS patients. While likely, this boon has been assessed by only one study to date (162). Elective patients may also benefit from a more rested surgeon, having spent less time operating after-hours.

For staff, registrars received greater supervision. Data not reported in Publication eight includes rates of consultant attendance in theatre, which were usually higher within the ASU model (Table 2). Registrars may benefit from concentrated exposure to EGS patients. Additionally, protected periods of rest may improve their knowledge acquisition; '*fatigue [is] ... also likely to undermine the learning ability of junior staff*' (52).

Table 2. Rates of consultant in-theatre during emergency general surgical cases.

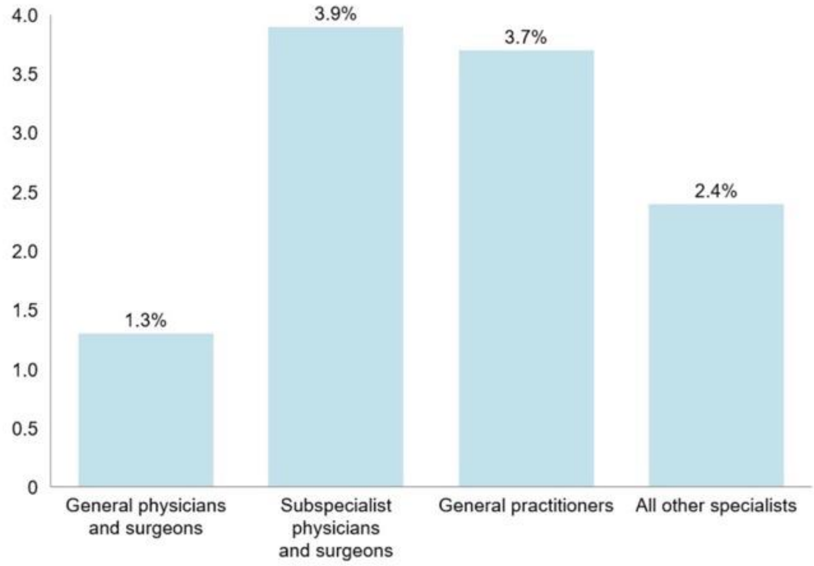
Year	1st author	Procedure	Traditional	ASU	p value
2009	Agrawal (209)	Cholecx	10/45 (22%)	35/118 (30%)	0.34
2010	Gandy (191)	Appx	57/176 (32%)	106/226 (47%)	0.003 *
2010	Lehane (121)	Cholecx	49/87 (56%)	85/115 (74%)	0.009 *
2018	Mathur (41)	Cholecx	116/135 (86%)	107/112 (96%)	0.01 *
2019	Kinnear (153)	Appx	99/465 (21%)	417/749 (56%)	<0.001 *

Comparisons were assessed with Pearson's chi-square test. All tests were two-tailed, and significance was assessed at the 5% alpha level. *: statistically significant. 1st: first. Appx: appendicectomy. ASU: acute surgical unit. Cholecx: cholecystectomy.

The ASU model may also complement workforce planning, by increasing the number and duration of surgeon providing EGS on-call. Traditionally, '*surgeons toward the end of their career tend to opt out of emergency rosters because of the unpredictability and lack of control of their hospital attendance when on-call*' (121). An ASU model offers shorter duration on-call, clear handover routines and protected time off-call. This may go some way to make EGS practice more attractive; '*The quarantining of surgeons' emergency commitments has potential to reduce surgeons' perceptions of emergency surgery as a burden that detracts from their elective work*'

(52). Additionally, documented higher satisfaction (publication six, Wanis *et al.* (165)) may aid workforce attraction and retention. Career satisfaction is the single greatest determinant of retirement age amongst general surgeons (337). The potential for the ASU model to bolster surgical workforce planning is of huge importance. As the Royal College of Surgeons of England stated in their inaugural report '*Surgical Workforce 2010*', '*The training of surgeons is a long and expensive process. ... [The aim is] to achieve ... a match between supply and demand. This is a challenging task because there are so many variables in the equation*' (400). Challenges include cost (AUD >$900,000 per surgeon (431)), lengthy duration, requirement for both experiential and rote learning, inter-specialty variation, desire for fewer weekly hours, workforce feminisation and population urbanisation (400, 432). Throughout developed nations, providing sufficient general surgeons is increasingly problematic. In almost all European nations, the ratio of specialists to generalists continues to climb (433). The Royal College of Surgeons of England laments '*difficulties in having an … available surgical workforce for … EGS patients*' (169). In the USA the supply of general surgeons is failing to keep pace with specialisation (Table 3) and the American College of Surgeons noted in 2017 '*there were only enough general surgeons to meet 69 percent of the demand for care in rural areas [and] 75 percent of the demand for care in suburban areas*' (432). Closer to home, the Royal Australasian College of Surgeons warned in 2011, '*unless there is a substantial increase in the number of graduating surgeons, Australia faces a surgical workforce crisis within the next fifteen years*' (431). Shortages are disproportionately growing within in general surgery. Despite seemingly reassuring historical figures (Table 4), the Australian Department of Health warns '*generalist non-GP specialists are vital to enabling the local delivery of high-quality care to Australian communities … However, since 2013 the number of* *registered subspecialists has grown at three times the annual rate of general physicians and surgeons*' (Figure 3) (434). The ASU model's ability to address barriers to training and retaining general surgeons is therefore highly appealing.

Figure 3. Compound annual growth rates of medical specialties in Australia 2013-17.



From the Australian Department of Health (434).

10.5. Guidance for general surgical departments considering establishing an ASU

We now provide brief guidance for surgeons considering moving to an ASU model. The main requirements have been partly detailed in this chapter's earlier section on health policy guidance. These are four or more general surgeons (whom we recommend rostering on-call for maximum four consecutive days), protected operating theatre access for EGS patients in business hours and EGS minimum throughput of 500 procedures and 1,000 admissions per annum. The national cross-sectional study identified five examples within Australia whereby the ASU model had been established and then abandoned (Appendix 8). In all cases, these were due to units not meeting the above requirements, with combinations of too few surgeons, inadequate daytime theatre access or rostering surgeons on-call for seven consecutive days.

The ASU model's 'soft' requirement is appetite for change. Structural change is disruptive, and requires an accepted chronic problem with the status quo, such as delays in reviewing EGS patients in the emergency department, frequent elective interruptions or after-hours operating. Start-up funding is not mandatory, with many centres simply reallocating existing staff and theatres. However, short term funding has been used to establish some ASUs, with the expectation of subsequent cost savings. For example, in Geelong Hospital, Australia '*Funding was provided to five pilot sites … the funds were used to provide sessional payments for the on-site general surgeons and for a project manager to collect the data*' (193). A follow-up study at the same site later notes '*We have continued to implement EGS operating sessions beyond the study period, and this has been achieved without extra funding*' (155). Similarly, in Victoria Hospital, Canada '*Funding for an additional 13 hours of operating time was provided by a onetime regional project grant to address long wait times in the emergency department. After the project year, funding continued to be provided by the hospital because ACCESS was such a successful program*' (161).

An additional important concept during implementation is change management. Once again, the experience of the acute *medical* unit movement is instructive. Leaders of successful examples recommend several key steps (141, 435);

- Involve all stakeholders from the outset, including of course general surgery, but also the emergency department, theatre coordinators, ward nurses and hospital administrators.

- Help clinicians accept that reorganisation will involve a change in practices
- Link staff with staff in their same role at other organisation who have already undergone the change. This should occur for medical, nursing and administrative staff, and for both junior and senior personnel.
- Show that resources are not needed before they are taken away
- Consider creating extra temporary posts to facilitate the change.

10.6. Further measures to improve EGS services

The overall aim of this thesis has been '*to improve care for EGS patients*.' The prime focus has been on the ASU model and its ability to achieve this aim. There remain additional mechanisms separate to staff and theatre allocation that may also be beneficial.

The first and most important is ongoing surgical leadership. While elective surgical waitlists have become repeatedly discussed in the press and political area (5, 98), there is a lack of visibility and conversation regarding EGS patients; '*the extent of emergency surgical care that is required … is underappreciated*' (81). Emergency surgical workload is perceived as unpredictable, and therefore hard to plan for. To the contrary, as General Surgeons Australia states, '*it is now abundantly clear that emergency general surgery workload is predictable within an institution and does not vary markedly from day to day*' (66). Only through representation will the needs of these EGS patients and staff be best addressed, rather than defined for them; '*if you're not at the table, you're on the menu*' (436). Surgeons must seek out positions on decision making bodies, including hospital peri-operative boards, state and national surgical societies and political bodies. While surgeons may envisage their role as partnering with the patient in and out of the operating room, they are also viewed as leaders within the hospital and the wider community. Work on committees may be perceived as time consuming, slow moving and poorly remunerated, but is vital to advocating for the right changes. These policy making bodies are challenged by constant churn in hospital administrators and health ministers; '*the lack of continuity in management in many ... hospitals places significant barriers to progress the development of ... clinical services*' (395). A stable medical presence is particularly important in the face of this turnover.

The next measure is creation and retention of the EGS surgeon pool. For existing surgeons, time off-call must be protected, and remuneration improved for delivering EGS care. For general surgical trainees, competence must be ensured in emergency procedures. In Australia, in addition to the existing quarterly departmental assessments, trainee-selected procedural assessments and exit fellowship exam, this might include a mandatory logbook, whereby supervisors confirm safe independent performance of core emergency operations.

Physical wards solely for EGS patients should be championed as centres of education and excellence. Housing all (or most) EGS patients in a concentrated area will allow not only efficient ward rounds (35, 102), and also several other synergies. The most important of these are nursing. Through constant exposure to EGS patients, staff develop familiarity and expertise, creating '*a consistent nursing team that is familiar with ACS practices*' (44). This will aid nurse satisfaction and retention (437), and improve patient care. This should be supported through the protection and expansion of senior EGS nursing positions. Many centres already have such arrangements in place (166, 195). Centres should also support and fund career pathways in EGS nursing, including in-house clinical training (195) and more formal delivery for diploma or masters level qualifications, as currently already exists in other areas such as paediatrics, emergency medicine and intensive care. There is clearly appetite for such change; '*Nurses will also benefit from a defined career path in emergency surgery, a coordinated approach to a previously unplanned workload and opportunities for career advancement in a previously professionally unstructured specialty*' (412). Outside of nursing, allied health will also develop specific proficiency (41), while medical students and junior doctors will benefit from repetitious exposure to similar presentations. Dedicated EGS wards will also facilitate research.

10.7. Thesis limitations

This thesis is limited primarily by the level of evidence. The eight publications were all non-randomised, as were all identified studies in the two systematic reviews (publications seven and eight). This is unsurprising, as pseudo- or true-randomisation of patients to either Traditional or ASU structures would require simultaneous staffing and simultaneous operating theatres, which would be prohibitively resource-intensive. However, potential biases are likely to be greater for non-randomised studies. For example, 48 of the 77 studies identified in the larger systematic review were at medium to high risk of bias (Appendix 19).

The ASU literature also suffers from lack of consensus in terms. As summarised in publication eight's '*Table 2. Variations in study definitions for selected outcomes*', works vary widely in their meaning of the terms time to review, time to theatre and after-hours. This makes comparisons between studies somewhat blurred.

Conclusions

Compared with the Traditional structure, the ASU model delivers superior outcomes. Patients experience reduced complications and hospital stay, staff perform less after-hours operating and enjoy safer working hours and greater satisfaction, and costings are equivalent or superior. The ASU model should be promoted in health policy as standard of care for departments of adequate size and patient load. Further measures may include improved valuation of EGS services and development of regionalised EGS networks. Future research may include cost analyses, patient reported outcomes, validation of key performance indicators, assessment of the ASU model in low-income settings and application of similar models outside general surgery.

Appendices

Appendix 1. Chapter 1; Time of appendicectomy

Year	1st author	Nation	After-hours definition	Enrolment period (months)		Traditional patients (n)		ASU patients (n)	
				Traditional	ASU	After-hours	In-hours	After-hours	In-hours
2006	Earley (179)	USA	36	36	1600 - 0800	66	127	68	167
2010	Gandy (191)	Aust.	12	12	1700 - 0800	116	176	118	226
2013	Brockman (193)	Aust.	12	12	0000 - 0800	44	351	16	357
2013	Pillai (204)	NZL	29	31	1630 - 0730	355	875	336	982
2013	Poh (194)	Aust.	12	12	1800 - 0800	78	254	48	281
2014	Beardsley (195)	Aust.	3	3	1800 - 0700	32	84	15	66
2014	Fu (189)	Taiwan	12	12	1700 - 0800	57	146	116	159
2014	Lancashire (196)	Aust.	12	12	1800 - 0730	81	247	75	548
2014	Suen (198)	Aust.	24	24	1700 - 0800	126	276	142	399
2014	Wright	USA	18	12	0700 - 1900	327	516	188	341
2017	Allaway (200)	Aust.	24	24	1900 - 0700	130	277	428	1476
2017	Martin (208)	UK	unclear	unclear	Unclear	28	257	27	272
2017	Pritchard (128)	Aust.	24	24	1800 - 0800	189	421	156	380
2017	Yahya (129)	Aust.	18	18	1800 - 0800	112	256	62	300
2018	McGrath (205)	Ireland	4	5	unclear	48	129	68	177
2019	Hx (188)	SGP	6	6	1600 - 0730	107	192	79	179
2019	Kinnear (153)	Aust.	30	30	1800 - 0800	128	465	160	749
Total						2024 (40%)	5049	2102 (30%)	7059

Aust.: Australia. ASU: acute surgical unit. N: number. NZL: New Zealand. SGP: Singapore. UK: United Kingdom. USA: United States of America. 1st: first.

Appendix 2. Chapter 5; Questionnaire template

Based on the template developed by Jones CH, O'Neill S, McLean KA, Wigmore SJ, Harrison EM. Patient experience and overall satisfaction after emergency abdominal surgery. BMC Surg. 2017 Jul 1;17(1):76. For each item, participants respond: I experienced this… at all times / sometimes / not at all. The exception is the final question, where patients provide an overall rating 0-10 of their experience.

	At all times	Sometimes	Not at all
Admission			
1. Sufficient information in ED	☐	☐	☐
2. Sufficient privacy in the ED	☐	☐	☐
3. Did not experience a long wait for bed in ward	☐	☐	☐
Ward Environment			
4. No night-time noise from other patients	☐	☐	☐
5. No night-time noise from staff	☐	☐	☐
6. High levels of ward cleanliness	☐	☐	☐
7. No threatening behaviour from other patients or visitors	☐	☐	☐
8. High satisfaction with the food	☐	☐	☐
9. Sufficient help at mealtimes	☐	☐	☐
10. Enough nurses on the ward	☐	☐	☐
11. Sufficient privacy for clinical discussions	☐	☐	☐
12. Sufficient privacy for examination and treatment	☐	☐	☐
Patient-staff interaction			
13. Confidence and trust in doctors responsible for care	☐	☐	☐
14. Satisfaction with level of seniority of medical staff	☐	☐	☐
15. Did not experience doctors talking in front of patients as if not present	☐	☐	☐
16. Confidence and trust in nurses	☐	☐	☐
17. Did not experience nurses talking in front of patients as if not present	☐	☐	☐
18. Staff to talk to about worries and fears	☐	☐	☐
19. Sufficient emotional support from staff	☐	☐	☐
20. No pain	☐	☐	☐
21. Sufficient pain control from staff	☐	☐	☐

Information and involvement in treatment

22. Important questions answered by doctors ☐ ☐ ☐
23. Important questions answered by nurses ☐ ☐ ☐
24. Involvement in decisions about treatment ☐ ☐ ☐
25. Confidence in decisions made about treatment ☐ ☐ ☐
26. Sufficient information given about treatment ☐ ☐ ☐
27. Sufficient explanation of risks and benefits of surgery ☐ ☐ ☐
28. Sufficient explanation of operation details ☐ ☐ ☐
29. Questions answered about surgery ☐ ☐ ☐
30. Sufficient pre-op explanation of what to expect post-op ☐ ☐ ☐
31. Sufficient explanation from anaesthetists ☐ ☐ ☐
32. Sufficient post-op explanation of operation findings ☐ ☐ ☐

Discharge Process

33. Involvement in discharge decision-making ☐ ☐ ☐
34. Sufficient notice prior to discharge ☐ ☐ ☐
35. Discharge not delayed ☐ ☐ ☐
36. Provision of written information ☐ ☐ ☐
37. Explanation of purpose of discharge medication ☐ ☐ ☐
38. Explanation how to take discharge medication ☐ ☐ ☐
39. Warning of danger signals to look out for at home ☐ ☐ ☐
40. Consideration of family situation in planning discharge ☐ ☐ ☐
41. Sufficient information given to family ☐ ☐ ☐
42. Information given for who to contact if concerned ☐ ☐ ☐
43. Discharged with required equipment/ home adaptations ☐ ☐ ☐
44. Discharged with all required community/ social care ☐ ☐ ☐

Overall Experience

45. Treated with dignity ☐ ☐ ☐
46. Felt well-looked after in hospital ☐ ☐ ☐
47. Overall (please circle/ indicate a number)

I had a very poor experience — I had a very good experience

0 1 2 3 4 5 6 7 8 9 10

Appendix 3. Chapter 6; Australian hospitals that have published their emergency general surgery model.

Location	Publication year	EGS model
Australian Capital Territory		
The Canberra Hospital, Canberra	2014	Acute surgical unit (195)
New South Wales		
John Hunter Hospital, Newcastle	2009	Acute surgical unit (120)
Nepean Hospital, Nepean	2010	Acute surgical unit (166)
Prince of Wales Hospital, Sydney	2009	Acute surgical unit (190)
St George Hospital, Sydney	2017	Sub-specialty model (423)
Northern Territory		
-		-
Queensland		
Gold Coast Hospital, Gold Coast	2014	Acute surgical unit (196)
Nambour General Hospital, Nambour	2011	Acute surgical unit (192)
South Australia		
Lyell McEwin Hospital, Adelaide	2017	Acute surgical unit (163)
Tasmania		
-		-
Victoria		
Bendigo Health, Bendigo	2017	Acute surgical unit (128)
Dandenong Hospital, Melbourne	2012	Acute surgical unit (438)
Eastern Health, Melbourne	2017	Acute surgical unit (201)
Geelong Hospital, Bendigo	2013	Acute surgical unit (155)
Latrobe Regional Hospital, Traralgon	2016	Traditional (439)
Monash Medical Centre, Melbourne	2013	Acute surgical unit (194)
Royal Melbourne Hospital, Melbourne	2014	Acute surgical unit (198)
Wagga Wagga Health Service, Wagga Wagga	2013	Acute surgical unit (162)
Western Australia		
Fiona Stanley Hospital, Perth	2018	Acute surgical unit (411)
Fremantle Hospital, Fremantle	2010	Acute surgical unit (157)

EGS: Emergency general surgery.

Appendix 4. Chapter 6; Australian Institute of Health and Welfare hospital peer groups relevant to general surgery, abbreviated.

Hospital type	Location	Workload †	Number ‡
Major	Major cities, *or* Regional	>20,000 ACASPA, *or* >16,000 ACASPA, respectively.	31
Large metropolitan	Major cities	>10,000 ACASPA	34
Large regional	Regional, *or* Remote	>8,000 ACASPA, *or* >5,000 ACASPA, respectively.	26
Medium metropolitan	Major cities	>2,000 ACASPA	22
Medium regional	Regional	>2,000 separations p.a., unadjusted	21
Small regional	Regional	<2,000 separations p.a., unadjusted	95 §
Small remote	Remote	<2,000 separations p.a., unadjusted	
Children's	N/a	Offer paediatric surgery only	4 §
Unpeered	N/a	Prison medical services, dental hospitals, and hospitals not defined above	10 §

ACASPA: acute casemix-adjusted separations per annum. P.a.: per annum. †: includes patient separations across all specialties, including medicine, surgery, psychiatry and other. ‡: as published by the Australian Institute of Health and Welfare, December 2018 (440). Numbers do not include one additional site introduced subsequent to AIHW list publication (Northern Beaches Hospital, large metropolitan hospital, New South Wales), which was included in the study. §: not included in study; see Methods.

Appendix 5. Chapter 6; Telephone questionnaire template.

On-call registrar

Following introduction, verbal consent, and explanation of the study's confidential and voluntary nature;

i. Are you responsible for emergency general surgical (EGS) referrals today?
ii. Are you an accredited or unaccredited registrar?
iii. What is your post-graduate year?
iv. How many registrars share on-call?
v. What is your longest duration on-call?
vi. Can you please describe your hospital's EGS model?
vii. When the registrar is on-call, do they still have elective duties?
viii. When the consultant is on-call, do they still have elective duties?
ix. Is there an emergency operating list (need not be specific to EGS) every weekday?
x. Is there any protected EGS operating time?
xi. Is there routine handover of EGS patients?
xii. How are emergency urological patients managed?
xiii. How would you self-assess your satisfaction with the EGS model on a scale -2 to +2?
xiv. What is good about your hospital's EGS model?
xv. What could be improved?
xvi. How would you self-assess your operative exposure -2 to +2?

General Surgery head of unit or senior surgeon

Following study explanation, verbal consent, and explanation of confidentiality and voluntary nature;

i. Can you please confirm your role in the EGS service at your hospital?
ii. Can you please describe your hospital's EGS model?
iii. When the registrar is on-call, do they still have elective duties?
iv. When the consultant is on-call, do they still have elective duties?
v. How many consultants participate in the EGS on-call roster, and what is the on-call duration?
vi. If an acute surgical unit (ASU) or Hybrid model exists, what year and why did this commence and has financial assessment occurred compared with the prior model?
vii. If not, have these models been considered, and if so, what barriers prevented commencement?
viii. Are there dedicated emergency general surgery (EGS) beds/ ward?
ix. Is there an emergency operating list (need not be specific to EGS) every weekday?
x. Can you please describe your hospital's trauma model?
xi. Do you have any subspecialty trauma surgeons (not part of another specialty)?
xii. What is good about your hospital's EGS model?
xiii. What could be improved?
xiv. How would you self-assess your satisfaction with the EGS model on a scale -2 to +2?

Appendix 6. Chapter 6; Australian medium- to major-sized public hospitals contacted.

Hospital	State	Local Hospital Network (LHN)	Peer group
Calvary Public Hospital	ACT	Australian Capital Territory	Medium metropolitan hospitals
The Canberra Hospital	ACT	Australian Capital Territory	Medium metropolitan hospitals
Armidale Hospital	NSW	Hunter New England	Medium regional hospitals
Auburn Hospital	NSW	Western Sydney	Medium metropolitan hospitals
Bankstown Lidcombe Hospital	NSW	South Western Sydney	Large metropolitan hospitals
Bathurst Health Service	NSW	Western NSW	Large regional hospitals
Belmont Hospital	NSW	Hunter New England	Medium metropolitan hospitals
Blacktown Hospital	NSW	Western Sydney	Large metropolitan hospitals
Bowral Hospital	NSW	South Western Sydney	Medium regional hospitals
Broken Hill Hospital	NSW	Far West	Medium regional hospitals
Calvary Mater Newcastle Hospital	NSW	Hunter New England	Large metropolitan hospitals
Campbelltown Hospital	NSW	South Western Sydney	Large metropolitan hospitals
Canterbury Hospital	NSW	Sydney	Medium metropolitan hospitals
Coffs Harbour Hospital	NSW	Mid North Coast	Large regional hospitals
Concord Hospital	NSW	Sydney	Major hospitals
Dubbo Hospital	NSW	Western NSW	Large regional hospitals
Fairfield Hospital	NSW	South Western Sydney	Medium metropolitan hospitals
Gosford Hospital	NSW	Central Coast	Large metropolitan hospitals
Goulburn Hospital	NSW	Southern NSW	Medium regional hospitals
Grafton Base Hospital	NSW	Northern NSW	Medium regional hospitals
Griffith Base Hospital	NSW	Murrumbidgee	Large regional hospitals
Hawkesbury Hospital	NSW	Nepean Blue Mountains	Medium metropolitan hospitals
Hornsby Ku-ring-gai Hospital	NSW	Northern Sydney	Large metropolitan hospitals
John Hunter Hospital	NSW	Hunter New England	Major hospitals
Kempsey Hospital	NSW	Mid North Coast	Medium regional hospitals
Lismore Hospital	NSW	Northern NSW	Large regional hospitals
Liverpool Hospital	NSW	South Western Sydney	Major hospitals
Maitland Hospital	NSW	Hunter New England	Medium metropolitan hospitals
Manly Hospital	NSW	Northern Sydney	Large metropolitan hospitals
Manning Hospital	NSW	Hunter New England	Large regional hospitals
Mona Vale Hospital	NSW	Northern Sydney	Large metropolitan hospitals
Mount Druitt Hospital	NSW	Western Sydney	Medium metropolitan hospitals
Nepean Hospital	NSW	Nepean Blue Mountains	Major hospitals
Northern Beaches Hospital	NSW	Northern Sydney	Large metropolitan hospitals
Orange Health Service	NSW	Western NSW	Large regional hospitals
Port Macquarie Hospital	NSW	Mid North Coast	Large regional hospitals
Prince of Wales Hospital	NSW	South Eastern Sydney	Major hospitals
Royal Hospital for Women	NSW	South Eastern Sydney	Medium metropolitan hospitals
Royal North Shore Hospital	NSW	Northern Sydney	Major hospitals
Royal Prince Alfred Hospital	NSW	Sydney	Major hospitals
Ryde Hospital	NSW	Northern Sydney	Medium metropolitan hospitals
Shellharbour Hospital	NSW	Illawarra Shoalhaven	Medium metropolitan hospitals
Shoalhaven Hospital	NSW	Illawarra Shoalhaven	Large regional hospitals
South East Regional Hospital	NSW	Southern NSW	Medium regional hospitals
St George Hospital NSW	NSW	South Eastern Sydney	Major hospitals
St Vincent’s Hospital	NSW	St Vincent's Health Network	Major hospitals
Sutherland Hospital	NSW	South Eastern Sydney	Large metropolitan hospitals
Tamworth Hospital	NSW	Hunter New England	Large regional hospitals
The Tweed Hospital	NSW	Northern NSW	Large metropolitan hospitals
Wagga Wagga Rural Referral Hospital	NSW	Murrumbidgee	Large regional hospitals
Westmead Hospital	NSW	Western Sydney	Major hospitals
Wollongong Hospital	NSW	Illawarra Shoalhaven	Major hospitals
Wyong Hospital	NSW	Central Coast	Large metropolitan hospitals
Alice Springs Hospital	NT	Central Australia (NT)	Large regional hospitals
Royal Darwin Hospital	NT	Top End (NT)	Major hospitals
Bundaberg Base Hospital	Qld	Wide Bay	Large regional hospitals
Caboolture Hospital	Qld	Metro North (Qld)	Medium metropolitan hospitals
Cairns Hospital	Qld	Cairns and Hinterland	Large regional hospitals
Caloundra Health Service	Qld	Sunshine Coast	Medium metropolitan hospitals
Gladstone Hospital	Qld	Central Queensland	Medium regional hospitals
Gold Coast University Hospital	Qld	Gold Coast	Major hospitals
Gympie Hospital	Qld	Sunshine Coast	Medium regional hospitals
Hervey Bay Hospital	Qld	Wide Bay	Large regional hospitals
Ipswich Hospital	Qld	West Moreton	Large metropolitan hospitals
Logan Hospital	Qld	Metro South (Qld)	Large metropolitan hospitals
Mackay Base Hospital	Qld	Mackay	Large regional hospitals
Maryborough Hospital	Qld	Wide Bay	Medium regional hospitals
Mater Hospital Brisbane	Qld	Not applicable	Large metropolitan hospitals

Mount Isa Base Hospital	Qld	North West (Qld)	Medium regional hospitals
Nambour General Hospital	Qld	Sunshine Coast	Large metropolitan hospitals
Princess Alexandra Hospital	Qld	Metro South (Qld)	Major hospitals
Queen Elizabeth II Jubilee Hospital	Qld	Metro South (Qld)	Large metropolitan hospitals
Redcliffe Hospital	Qld	Metro North (Qld)	Large metropolitan hospitals
Redland Hospital	Qld	Metro South (Qld)	Medium metropolitan hospitals
Robina Hospital	Qld	Gold Coast	Medium metropolitan hospitals
Rockhampton Hospital	Qld	Central Queensland	Large regional hospitals
Royal Brisbane & Women's Hospital	Qld	Metro North (Qld)	Major hospitals
The Prince Charles Hospital	Qld	Metro North (Qld)	Major hospitals
The Townsville Hospital	Qld	Townsville	Major hospitals
Toowoomba Hospital	Qld	Darling Downs	Large regional hospitals
Flinders Medical Centre	SA	Southern Adelaide	Major hospitals
Lyell McEwin Hospital	SA	Northern Adelaide	Large metropolitan hospitals
Modbury Hospital	SA	Northern Adelaide	Large metropolitan hospitals
Mount Gambier and Districts Health Service	SA	Country Health SA	Medium regional hospitals
Noarlunga Public Hospital	SA	Southern Adelaide	Medium metropolitan hospitals
Port Augusta Hospital and Regional Health Services	SA	Country Health SA	Medium regional hospitals
Repatriation General Hospital	SA	Southern Adelaide	Large metropolitan hospitals
Royal Adelaide Hospital	SA	Central Adelaide	Major hospitals
The Queen Elizabeth Hospital	SA	Central Adelaide	Large metropolitan hospitals
Whyalla Hospital and Health Services	SA	Country Health SA	Medium regional hospitals
Launceston General Hospital	Tas	Tasmanian Health Service	Large regional hospitals
Mersey Community Hospital	Tas	Tasmanian Health Service	Medium regional hospitals
North West Regional Hospital	Tas	Tasmanian Health Service	Large regional hospitals
Royal Hobart Hospital	Tas	Tasmanian Health Service	Major hospitals
Angliss Hospital	Vic	Eastern Health	Medium metropolitan hospitals
Austin Hospital [Heidelberg]	Vic	Austin Health	Major hospitals
Ballarat Health Services [Base Campus]	Vic	Ballarat Health Services	Large regional hospitals
Box Hill Hospital	Vic	Eastern Health	Large metropolitan hospitals
Casey Hospital	Vic	Monash Health	Medium metropolitan hospitals
Dandenong Campus	Vic	Monash Health	Large metropolitan hospitals
Frankston Hospital	Vic	Peninsula Health	Large metropolitan hospitals
Goulburn Valley Health [Shepparton]	Vic	Goulburn Valley Health	Large regional hospitals
Latrobe Regional Hospital [Traralgon]	Vic	Latrobe Regional Hospital	Large regional hospitals
Maroondah Hospital [East Ringwood]	Vic	Eastern Health	Large metropolitan hospitals
Mercy Hospital for Women	Vic	Mercy Public Hospital Inc.	Medium metropolitan hospitals
Monash Medical Centre [Clayton]	Vic	Monash Health	Major hospitals
Monash Medical Centre [Moorabbin]	Vic	Monash Health	Large metropolitan hospitals
Northeast Health Wangaratta	Vic	Northeast Health Wangaratta	Large regional hospitals
Royal Melbourne Hospital [Parkville]	Vic	Melbourne Health	Major hospitals
Royal Women's Hospital [Parkville]	Vic	Royal Women's Hospital	Medium metropolitan hospitals
Sandringham Hospital	Vic	Alfred Health	Medium metropolitan hospitals
St Vincent's Hospital [Fitzroy]	Vic	St Vincent's Hospital Ltd	Major hospitals
Sunshine Hospital	Vic	Western Health	Medium metropolitan hospitals
The Alfred	Vic	Alfred Health	Major hospitals
The Bendigo Hospital	Vic	Bendigo Health Care Group	Large regional hospitals
The Northern Hospital [Epping]	Vic	Northern Health	Large metropolitan hospitals
University Hospital Geelong	Vic	Barwon Health	Major hospitals
Werribee Mercy Hospital	Vic	Mercy Public Hospital Inc.	Medium metropolitan hospitals
West Gippsland Healthcare Group [Warragul]	Vic	West Gippsland Healthcare Group	Medium regional hospitals
Western Hospital [Footscray]	Vic	Western Health	Large metropolitan hospitals
Williamstown Hospital	Vic	Western Health	Medium metropolitan hospitals
Albany Hospital	WA	WA Country Health Service	Medium regional hospitals
Armadale-Kelmscott Memorial Hospital	WA	East Metropolitan Health Service	Large metropolitan hospitals
Fiona Stanley Hospital	WA	South Metropolitan Health Service	Major hospitals
Fremantle Hospital	WA	South Metropolitan Health Service	Large metropolitan hospitals
Geraldton Hospital	WA	WA Country Health Service	Medium regional hospitals
Joondalup Health Campus (Public)	WA	North Metropolitan Health Service	Large metropolitan hospitals
Kalgoorlie Hospital	WA	WA Country Health Service	Medium regional hospitals
Peel Health Campus	WA	South Metropolitan Health Service	Medium metropolitan hospitals
Rockingham General Hospital	WA	South Metropolitan Health Service	Large metropolitan hospitals
Royal Perth Hospital Wellington Street Campus	WA	East Metropolitan Health Service	Major hospitals
Sir Charles Gairdner Hospital	WA	North Metropolitan Health Service	Major hospitals
South West Health Campus	WA	WA Country Health Service	Medium regional hospitals
St John of God Midland Public Hospital	WA	Unknown	Large metropolitan hospitals
Swan District Hospital	WA	Unknown	Medium metropolitan hospitals

Appendix 7. Chapter 6; Reasons for and against Acute Surgical Unit model uptake.

Reasons for ASU/ Hybrid model implementation †	No.	Perceived barriers against commencing an ASU ‡	No.
Improve care of EGS patients	12	Insufficient EGS load	30
Reduce after-hours operating	11	Insufficient surgeons to both staff ASU and elective workload	11
Cater to rising EGS load	9	Insufficient emergency theatre access	9
Improve theatre access/ reduce TTT	8	Insufficient funding	5
Create surgeon protected off-call	6	Not cost effective	5
Reduce elective work interruptions	5	Current system works well	3
Publicised ASU benefits §	4	Would dilute registrar operative exposure	2
Government/ specialty-group report	3	Frequent patient handover in ASU model	2
Patient suffered complications due to surgeon unavailability in Trad. model	3	Change would disrupt older surgeons	1
To improve surgical registrar training	3		
To meet ED 4-hour NEAT rule (60)	3		
Positive ASU experience at prior site	2		
Increasing no. of employed surgeons	2		
To improve trauma care	2		
To cater to sub-specialty general surgeons seeking no on-call duties	1		
Total	74	Total	68

ASU: acute surgical unit. ED: emergency department. EGS: emergency general surgery. NEAT: National Emergency Access Target. In 2009, the Australian Federal Government introduced the 4-hour NEAT, defined as a target whereby 85% of patients must spend less than four hours in the emergency department (60). No.: number. Trad.: Traditional. TTT: time to theatre. †: reasons reported by 34 hospitals employing an ASU or Hybrid EGS model. ‡: reasons reported by 56 hospitals employing a Hybrid or Traditional model. §: includes publications, conference presentations or hospital visits.

Appendix 8. Chapter 6; Case vignettes of hospitals which reverted to Traditional or Hybrid structures following trial of an Acute Surgical Unit model.

Year commenced †	Post-ASU model	Reason(s) for reversion
2005-2009	Hybrid	Lack of protected EGS operating theatre access combined with fee-for-service surgeon contracts led to frequent unproductive daytime hours, and significant time spent operating after-hours. Seven consecutive days on-call for a team of one surgeon/ one registrar created unsustainably high workload/ fatigue when each team rotated on-call
2010-2014	Hybrid	As above (fatigue of seven consecutive days on-call) Disruptive to surgeons' private practice
2015-2019	Hybrid	Insufficient EGS load Too few surgeons to both staff ASU & elective work
2015-2019	Hybrid	As above (fatigue of seven consecutive days on-call)
2015-2019	Traditional	Too few surgeons to both staff ASU & elective work Too few major operations for trainee requirements ‡

ASU: acute surgical unit. †: Year of ASU commencement is reported as occurring at an unspecified point during a five-year range, for confidentiality. ‡: Registrars undergoing accredited training with General Surgery Australia are required to be scrubbed in for a minimum of 100 'major' cases per six-month term (441). Common 'major' cases include cholecystectomy and bowel resection, whereas common 'minor' cases include appendicectomy and simple hernia repair.

Appendix 9. Chapter 8; List of full text studies retrieved to assess eligibility.

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7. Lee T, Jain A. Audit of the implementation of a renal colic pathway in the accident and emergency department of a district general hospital. International Journal of Surgery. 2015;23(Supp 1):S123.
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13. Rapp DE, Wood NL, Wright JA, Booth BA, Colhoun A, Kramolowsky EV. Providing Access to Care through a 24-Hour Dedicated Stone Line. Urology Practice. 2017;4(1):43-7.
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16. Trigylidas TE, Michael J, Schroeder L, Gatti J, Wickham A, Jain S. Timely management of testicular torsion: A collaborative quality improvement approach. Academic Emergency Medicine. 2018;25 (Supplement 1):S240-S1.

Appendix 10. Chapter 8; Data extraction pro-forma.

Reviewer:	one/ two	**Data extraction:**	1st/ 2nd
Study year:		**1st author:**	
Nation:			
Patient group:			
Patients excluded:			

Design:	Retrospective/ prospective	**Controls:**	Historical/ contemporary
Funding			
Ethics approval			
Conflict of interest			

Emergency urological patient care structure:

Control	
Intervention	

	Study duration (mo)	**Patients (n)**	**Mean age (years)**	**Female (%)**
Control				
Intervention				

	Time to review (hours)	**Time to theatre (hours)**	**In-hours operating (%)**
Control			
Intervention			

	Other interval (hours)	**Length of stay (days)**	**Complications (%)**
Control			
Intervention			

	Other outcome	**Other outcome**	**Other outcome**
Outcome			
Control			
Intervention			

Additional notes	

Mo: months. N: number. %: percentage.

Appendix 11. Chapter 8; Reviewer guidelines for assessing risk of bias.

Cohort studies; Guide for completing the Newcastle-Ottawa Quality Assessment Scale.

1. SELECTION

Representativeness of exposed cohort ★

Scoring studies will define and enrol adult emergency urological patients without further restriction by age, gender, time of day, disease severity or other limitation. Studies will be permitted to assess sub-groups, such as those presenting with testicular torsion or renal colic.

Selection of non-exposed cohort ★

To score, these must meet the requirements for the Exposed Cohort, be from the same centre(s), and either have an enrolment period of the same duration or be approximately matched in sample size.

Ascertainment of exposure ★

Scoring studies will reference hospital records.

Demonstration outcome of interest not present at start of study ★

Not applicable regarding this systematic review's primary outcomes of time to theatre, length of stay, cost.

2. COMPARABILITY

Comparability of cohorts on the basis of the design or analysis ★★

One star will be given if the mean or median age of each group is given, and there is no significant difference. A second star will be given if data for any other 'Representativeness' criteria are given (such as gender, American Society of Anesthesiologists physical status score or Charlson Comorbidity Index), with no significant difference between groups. Statements of no differences between groups, unsupported either by data or statistical comparison, are not sufficient.

3. OUTCOME

Assessment of outcome ★

Scoring studies will reference hospital records.

Was follow-up long enough for outcomes to occur? ★

Not applicable, as all outcomes occurred during the index admission, without a follow-up period.

Adequacy of follow up of cohorts ★

Not applicable, as all outcomes occurred during the index admission, without a follow-up period.

Case series; Guide for completing the modified Delphi quality appraisal tool.

Assign one point for each of the following eighteen questions which can be answered in the affirmative.

Study objective
Is the hypothesis/aim/objective of the study clearly stated?

Study population
Are the characteristics of the participants included in the study described?
Were the cases collected in more than one centre?
Are the eligibility criteria (i.e. inclusion and exclusion criteria) for entry into the study explicit and appropriate?
Were participants recruited consecutively?
Did participants enter the study at a similar point in the disease?

Intervention(s)
Was the intervention of interest clearly described?
Were additional interventions (co-interventions) clearly reported in the study?

Outcome measure
Are the outcome measures clearly defined in the introduction or methods section?
Were the relevant outcomes measured with appropriate objective and/or subjective methods?
Were the relevant outcomes measured before and after the intervention?

Statistical analysis
Were the statistical tests used to assess the relevant outcomes appropriate?

Results and conclusions
Was the length of follow-up reported?
Was the loss to follow-up reported?
Does the study provide estimates of the random variability in the data analysis of relevant outcomes?
Are adverse events reported?
Are the conclusions of the study supported by results?

Competing interests
Are both competing interests and sources of support for the study reported?

Appendix 12. Chapter 9; Preferred reporting items for systematic reviews and meta-analyses checklist.

Section/ topic	#	Checlist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	5
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Appx 2
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	8
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	8
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	9-10
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Appx 6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	11
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Appx 6
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	1

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097
For more information, visit: www.prisma-statement.org

Appendix 13. Chapter 9; Data extraction pro-forma

Reviewer:	one/ two	**Data extraction:**	1st/ 2nd
Study year:		**1st author:**	
Nation:		**City:**	
Single centre:	yes/ no		
Patient group:			
Patients excluded:			

Design:	Retrospective/ prospective	**Controls:**	Historical/ contemporary
Funding		**Ethics approval**	
Conflict of interest			

	Period (mo)	**Patients (n)**	**ASU design**
Trad			
ASU			

Outcomes

	Time to rv	Time to OT	A/h OT	LOS	Complxns	Mortality
Trad						
ASU						

	% open	Conversion	Neg appx	Perf appx	OT index admit	OT duration
Trad						
ASU						

	Boss in OT	ICU admit	Re-admit	ED re-pres'n	Cost	CT use
Trad						
ASU						

	% surgery	Pharm VTE prophylaxis	Mech VTE prophylaxis
Trad			
ASU			

Notes

Appx: appendix. ASU: acute surgical unit. A/h: after-hours. Complxns: complications. CT: computed tomography. ED: emergency department. ICU: intensive care unit. Mech: mechanical. Mo: months. N: number. Neg: negative. OT: operating theatre. Perf: perforated. Pharm: pharmocological. Rv: review. VTE: veno-thrombo-embolism. 1st: first. 2nd: second. %: percentrage.

Appendix 14. Chapter 9; Reviewer guidelines for completing the Newcastle-Ottawa Quality Assessment Scale.

1. SELECTION

Representativeness of exposed cohort ★

Must enrol a cohort of consecutive adult patients, without restriction by gender or age bracket, with emergency general surgical presentations only, with a dedicated surgical registrar, consultant or operating theatre.

Selection of non-exposed cohort ★

Must enrol a cohort of consecutive adult patients, without restriction by gender or age bracket, with emergency general surgical presentations only, and be managed within a Traditional model.

Ascertainment of exposure ★

Scoring studies will reference hospital records.

Demonstration outcome of interest not present at start of study ★

Not applicable.

2. COMPARABILITY

Comparability of cohorts on the basis of the design or analysis ★★

One star given if the mean or median age of each group is given, and there is no significant difference. Statements, unsupported by data, of no differences between groups are not sufficient. A second star is given if other demographic data are given, such as gender, American Society of Anaesthesiologist score or comorbidity score, with no difference between groups.

3. OUTCOME

Assessment of outcome ★

Scoring studies will reference hospital records.

Was follow-up long enough for outcomes to occur? ★

Not applicable, as follow-up during the inpatient period is adequate for all outcomes.

Adequacy of follow up of cohorts ★

Not applicable, as follow-up during the inpatient period is adequate for all outcomes.

Appendix 15. Chapter 9; Articles assessed for eligibility with full text if available.

Identified from database searches; 108 total
(3, 40-44, 51, 58, 76, 102, 121, 125-128, 132, 135-139, 150-154, 156-161, 163-166, 177-180, 184-186, 188-191, 194-200, 204, 205, 209, 211, 212, 249, 295, 322, 375, 378-381, 383-388, 391, 393, 437, 442-473)

Identified from grey literature; 17 total
(120, 130, 131, 133, 134, 155, 162, 183, 187, 193, 200, 201, 382, 474-477)

Eligible for qualitative review; 77 total
(3, 40-44, 51, 76, 102, 120, 121, 125-128, 130-139, 150-166, 177-180, 183-189, 191, 193-201, 204, 205, 209, 378-388)

Ineligible for review; 48 total
(58, 190, 200, 211, 212, 249, 295, 322, 375, 391, 393, 437, 442-477)

Reasons for systematic review ineligibility;

(190) Parasyn	no comparator cohort
(442) Zafar	includes elective patients
(212) Nagaraja	systematic review
(58) Page	systematic review
(443) Fearon	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(444) Karayiannis	overlap with 2017 Martin *et al*.
(445) Murphy	overlap with 2017 Murphy *et al*.
(446) Bruns	no comparator cohort
(211) Chana	systematic review
(447) Kalina	includes elective patients
(448) Schaetzel	did not assess introduction of acute surgical unit type model; compared different hospitals with different models
(449) Walsh	overlap with 2016 Bokhari *et al*.
(322) Bandy	did not assess introduction of acute surgical unit type model; compared different hospitals with different models
(450) Hannan	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(451) Martin Del Campo	includes elective patients
(391) Murphy	systematic review
(249) Balasubramanium	systematic review
(452) Bandy	did not assess introduction of acute surgical unit type model; compared different hospitals with different models
(437) Goh	overlap with 2018 Mathur *et al*.
(453) Khaskeli	no comparator cohort
(454) Achanta	did not assess introduction of acute surgical unit type model
(455) Barnett	did not assess introduction of acute surgical unit type model
(456) Becher	did not assess introduction of acute surgical unit type model
(457) Caballero	no raw patient data
(458) Fletcher	did not assess introduction of acute surgical unit type model

(459) Gaszynski	did not assess introduction of acute surgical unit type model; assessed specific pathway (abscess)
(460) Gebresellassie	did not assess introduction of acute surgical unit type model
(461) Ingraham	no raw patient data; national survey of models
(462) Kazem	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(463) Kinnear	no raw patient data; national survey of models
(295) Kinnear	no raw patient data; national survey of models
(464) Nally	did not assess introduction of acute surgical unit type model
(465) Nguyen	did not assess introduction of acute surgical unit type model
(393) Panagiotopoulou	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(466) Rakitin	no comparator cohort
(467) Rothstein	did not assess introduction of acute surgical unit type model
(468) Saleh	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(375) Vergis	systematic review
(469) Becher	no raw patient data
(470) Chaudhary	did not assess introduction of acute surgical unit type model
(471) DePesa	did not assess introduction of acute surgical unit type model
(472) Kaya	overlap with 2010 Gandy *et al*. and 2010 Lehane *et al*.
(473) Reeds	did not assess introduction of acute surgical unit type model; analysed surgical assessment unit
(474) Koirala	no raw patient data
(475) Lee	no raw patient data for specified primary or secondary outcomes
(476) Rodgers	no raw patient data
(477) Marks	no raw patient data
(200) Allaway	no raw patient data for specified primary or secondary outcomes

Appendix 16. Chapter 9; Systematic review sub-group analyses.

1.1 Length of stay

Length of stay was reported for patients with appendicitis (25 studies, 16,770 patients) (41, 43, 128, 153, 154, 165, 179, 183, 184, 186, 187, 189, 191, 193, 194, 196, 198, 200, 204, 205, 380, 381, 385, 387), cholecystitis (28 studies, 7,728 patients) (43, 51, 120, 121, 125-128, 130-132, 135-139, 154, 155, 160, 165, 177, 184, 185, 201, 209, 379, 381, 386), small bowel obstruction (four studies, 1,020 patients) (43, 165, 197, 199) and diverticulitis (one study, 60 patients) (382). Introduction of an ASU was associated with decreased length of stay for patients with appendicitis (mean difference [MD] 0.28 days shorter, 95% confidence interval [CI] 0.15-0.41 days, p<0.0001), cholecystitis (MD 1.09 days shorter, 95% CI 0.43 - 1.74, p=0.001), but not small bowel obstruction (MD 0.95 days longer, 95% CI 1.82 days shorter to 3.71 days longer, p=0.50) or diverticulitis (MD 3.0 days shorter, 95% CI not reported, p=0.35).

1.2 After-hours operating

The proportion of procedures performed after-hours was reported for patients with appendicitis (seventeen studies, 10,956 patients) (128, 153, 179, 186, 188, 189, 191, 193-196, 198, 200, 201, 204, 205, 387) and cholecystitis (fourteen studies, 4,018 patients) (51, 120, 126, 128, 130-132, 134, 136, 138, 139, 160, 201, 386). Establishing an ASU was associated with reduced rates of after-hours operating for patients with appendicitis (odds ratio [OR] 0.71, 95% CI 0.53 - 0.94, p=0.02) but not cholecystitis (OR 0.69, 95% CI 0.43 - 1.10, p=0.12).

1.3 Complications

Complication rates were reported for cohorts with appendicitis (seventeen studies, 13,401 patients) (153, 154, 179, 183, 186-189, 191, 193, 194, 196, 200, 204, 205, 381, 387), cholecystitis (nineteen studies, 6,037 patients) (51, 121, 125-127, 130-132, 135, 136, 138, 139, 154, 160, 185, 209, 379, 381, 386) and diverticulitis (one study, 60 patients) (382). ASU introduction was associated with reduced complications for patients with appendicitis (OR 0.67, 95% CI 0.55 - 0.83, p=0.0002) and cholecystitis (OR 0.60, 95% CI 0.44 - 0.81, p=0.001), but not diverticulitis (OR 0.86, 95% CI not reported, p=0.87).

1.4 Cost

Cost comparisons were reported for patients with appendicitis (four studies, 1,758 patients) (41, 154, 196, 381), cholecystitis (five studies, 1,485 patients) (41, 127, 154, 381, 386) and gallstone pancreatitis (one study, 194 patients) (178). ASU introduction was associated with significant cost savings in two cohorts with appendicitis (154, 381) and one each with cholecystitis (154) or gallstone pancreatitis (178). All other cohorts found costs were not significantly different (Table 1).

1.5 Time to surgical review

Time to surgical review was reported in cohorts of patients with appendicitis (seven studies, 2,054 patients) (43, 179, 195, 196, 380, 381, 385), cholecystitis (three studies, 525 patients) (43, 51, 381) and diverticulitis (one study, 60 patients) (382). ASU introduction was associated with significantly reduced time to surgical review for both patients with appendicitis (MD 1.41 hours shorter, 95% CI 0.67 - 2.15, p=0.0002) and cholecystitis (MD 0.66 hours shorter, 95% CI 0.13 - 1.19, p=0.01), but not diverticulitis (MD 0.2 hours, 95% CI not reported, p=0.39).

1.6 Time to theatre

Time to theatre was reported for patients with appendicitis (27 studies, 16,589 patients) (43, 128, 133, 152, 153, 155, 179, 180, 183, 186, 187, 189, 191, 194-196, 198, 200, 201, 204, 205, 378, 380, 381, 384, 385, 387), cholecystitis (24 studies, 5,984 patients) (43, 51, 120, 121, 125-128, 130-139, 152, 201, 209, 379, 381, 386), small bowel obstruction (three studies, 429 patients) (43, 152, 197) and diverticulitis (one study, 60 patients) (382). ASU commencement was associated with decreased time to theatre for patients with cholecystitis (MD 5.00 hours, 95% CI 3.06 - 6.93, p<0.00001), but not for appendicitis (MD 0.60 hours shorter, 95% CI 1.34 hours shorter to 0.14 hours longer, p=0.11), small bowel obstruction (MD 2.08 hours shorter, 95% CI 4.80 hours shorter to 0.65 hours longer, p=0.14) or diverticulitis (MD 6.4 hours, 95% CI not reported, p=0.21).

1.7 Mortality

Inpatient or 30-day mortality rates were reported for patients with appendicitis (four studies, 4,313 patients) (154, 196, 200, 204), cholecystitis (eight studies, 3,023 patients) (125, 132, 135, 136, 138, 154, 184, 379) and laparotomy (three studies, 1,772 patients) (40, 150, 388). ASU commencement did not affect mortality rates for any sub-group, including patients with appendicitis (OR 0.78, 95% CI 0.17 - 3.65, p=0.76), cholecystitis (OR 0.61, 95% CI 0.19 - 1.95) or undergoing laparotomy (OR 0.55, OR 0.24 - 1.25, p=0.15).

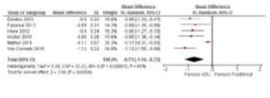
1.8 Re-admissions

Rates of re-admission, typically within 30 days, were reported for patients with appendicitis (five studies, 4,819 patients) (154, 186, 189, 193, 204) and cholecystitis (seven studies, 2,916 patients) (127, 130, 136, 138, 139, 154, 386). Introducing an ASU was associated with reduced re-admission rates for patients with cholecystitis (OR 0.42, 95% CI 0.26 - 0.66, p=0.0002), but not appendicitis (OR 1.17, 95% CI 0.86 - 1.58, p=0.33).

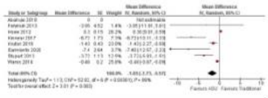
Appendix 17. Chapter 9; Meta-analyses of secondary outcomes and sub-group analyses. Sub-figure numbering continued from Figure 2 (main text).

Secondary outcomes

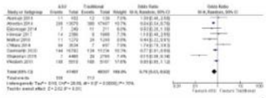
D. Any diagnosis - Time to surgical review



E. Any diagnosis - Time to theatre



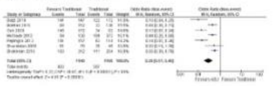
F. Any diagnosis – Mortality



G. Any diagnosis - Re-admission

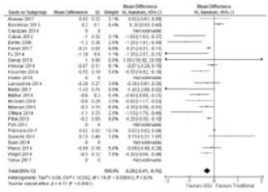
Secondary outcomes (continued)

H. Cholecystectomy - Index cholecystectomy

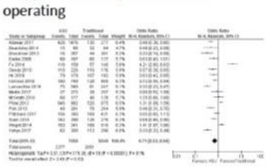


Sub-group analyses

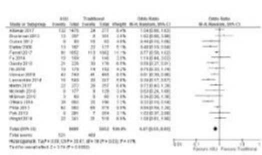
I. Appendicectomy - Length of stay



J. Appendicectomy - After hours operating

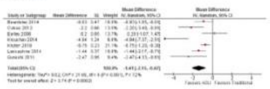


K. Appendicectomy – Complications

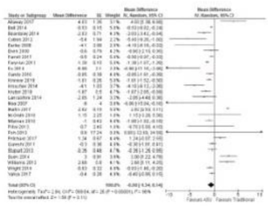


Sub-group analyses (continued)

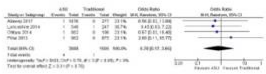
L. Appendicectomy - Time to surgical review



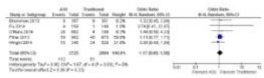
M. Appendicectomy - Time to theatre



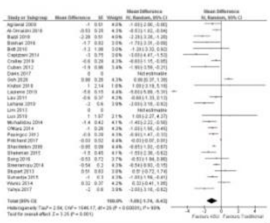
N. Appendicectomy – Mortality



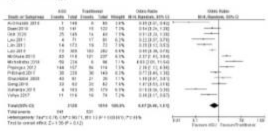
O. Appendicectomy - Re-admission



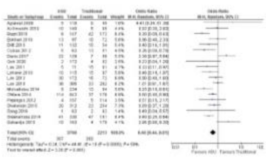
P. Cholecystectomy - Length of stay



Q. Cholecystectomy - After hours operating

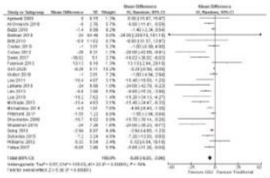


R. Cholecystectomy – Complications

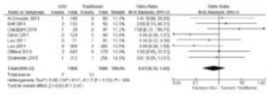


S. Cholecystectomy - Time to surgical review

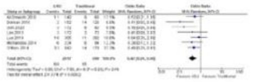
T. Cholecystectomy - Time to theatre



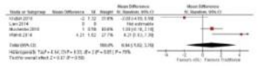
U. Cholecystectomy – Mortality



V. Cholecystectomy - Re-admission



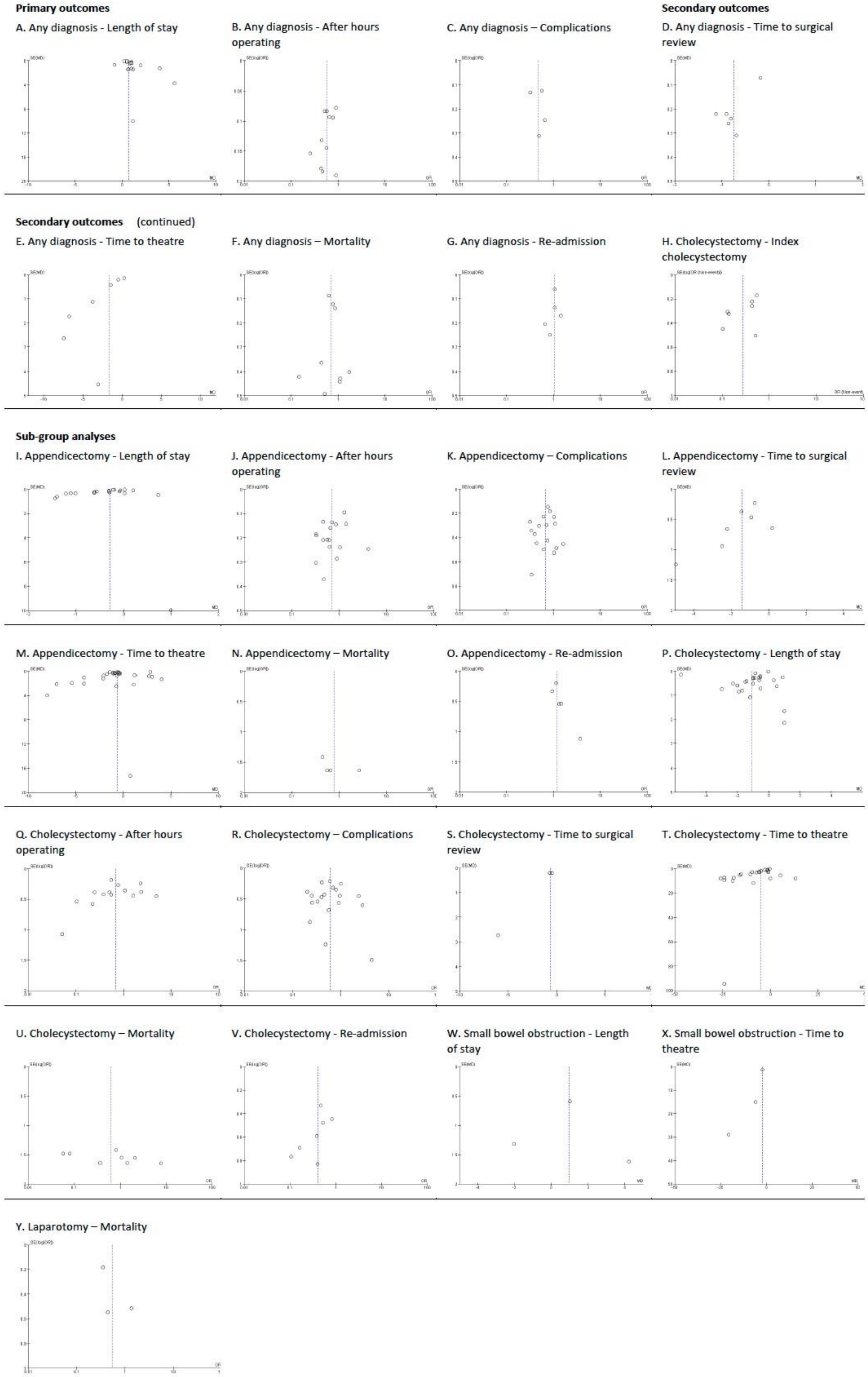
W. Small bowel obstruction - Length of stay



X. Small bowel obstruction - Time to theatre

Y. Laparotomy – Mortality

Appendix 18. Chapter 9; Funnel plots assessing for publication bias. Subfigure numbering continued from Figure 2 (main text).



Appendix 19. Chapter 9; Newcastle-Ottawa Quality Assessment Scale for included studies.

		1. Selection				2. Comparability	3. Outcome			Total
Year	First author	Representative-ness of exposed cohort	Selection non-exposed cohort	Ascertainment of exposure	Demonstration outcomes not present at start of study	Comparability of cohorts	Assessment of outcome	Was follow-up long enough for outcomes to occur?	Adequacy of follow up of cohorts	
2001	Addison (3)	*	*	*	*	-	*	*	*	7
2006	Earley (179)	*	*	*	*	*	*	*	*	8
2007	Maa (180)	*	*	*	*	-	*	*	*	7
2008	Ekeh (378)	*	*	*	*	*	*	*	*	8
2008	Sorelli (164)	*	*	*	*	-	*	*	*	7
2009	Agrawal (209)	*	*	-	*	**	-	*	*	7
2009	Shackleton (120)	*	*	*	*	-	*	*	*	7
2010	Britt (379)	*	*	*	*	**	*	*	*	9
2010	Cox (166)	*	*	*	*	-	*	*	*	7
2010	Gandy (191)	*	*	*	*	**	*	*	*	9
2010	Lapierre (177)	-	-	-	*	-	-	*	*	3
2010	Lehane (121)	*	*	*	*	**	*	*	*	9
2010	Milzman (183)	-	-	-	*	-	-	*	*	3
2010	Perry (102)	*	*	*	*	-	*	*	*	7
2010	Von Conrady (157)	*	*	*	*	-	*	*	*	7
2011	Lau (132)	*	*	*	*	**	*	*	*	9
2011	Qureshi (380)	*	*	*	*	**	*	*	*	9
2011	Western (156)	*	*	*	*	-	*	*	*	7
2012	Cubas (381)	*	*	*	*	**	*	*	*	9
2012	Hsee (159)	*	*	*	*	-	*	*	*	7
2012	Lee (382)	-	-	*	*	-	*	*	*	5
2012	Pepingco (160)	*	*	*	*	-	*	*	*	7
2012	Williams (133)	*	*	*	*	-	*	*	*	7
2013	Brockman (193)	*	*	*	*	*	*	*	*	8
2013	Faryniuk (152)	*	*	*	*	**	*	*	*	9
2013	King (162)	*	*	*	*	-	*	*	*	7
2013	Lim (130)	*	*	*	*	**	*	*	*	9
2013	McGlade (134)	*	*	*	*	-	*	*	*	7
2013	Pillai (204)	*	*	*	*	**	*	*	*	9
2013	Poh (194)	*	*	*	*	**	*	*	*	9
2013	Stupart (155)	*	*	*	*	-	*	*	*	7
2014	Anantha (161)	*	*	*	*	-	*	*	*	7
2014	Anantha (383)	*	*	*	*	-	*	*	*	7
2014	Atherton (150)	*	*	-	*	-	-	*	*	5
2014	Ball (384)	*	*	*	*	-	*	*	*	7
2014	Beardsley (195)	*	*	*	*	-	*	*	*	7
2014	Capizzani (184)	-	-	*	*	-	*	*	*	5
2014	Eijsvoogel (158)	-	-	*	*	**	*	*	*	7
2014	Fu (189)	*	*	-	*	**	-	*	*	7
2014	Krouchev (385)	-	-	*	*	-	*	*	*	5
2014	Lancashire (196)	*	*	*	*	**	*	*	*	9
2014	Lien (197)	*	*	*	*	**	*	*	*	9
2014	Michailidou (386)	*	*	*	*	**	*	*	*	9
2014	O'Mara (154)	*	*	*	*	-	*	*	*	7
2014	Sreeramoju (185)	-	-	*	*	-	*	*	*	5
2014	Suen (198)	*	*	*	*	*	*	*	*	8
2014	Wanis (165)	*	*	*	*	*	*	*	*	8
2014	Wright (186)	*	*	-	*	**		*	*	7
2015	Shakerian (40)	*	*	*	*	*	*	*	*	8
2015	Shakerian (125)	*	*	*	*	*	*	*	*	8
2015	Suhardja (126)	*	*	-	*	-	-	*	*	5
2016	Bokhari (127)	*	*	*	*	**	*	*	*	9
2016	Musiienko (199)	*	*	*	*	**	*	*	*	9
2016	Song (131)	-	-	-	*	*	-	*	*	4
2017	Allaway (200)	*	*	*	*	**	*	*	*	9
2017	Davis (135)	*	*	*	*	-	*	*	*	7
2017	Farrell (187)	*	*	-	*	*	-	*	*	6
2017	Kinnear (163)	*	*	*	*	**	*	*	*	9
2017	Martin (387)	-	-	*	*	-	*	*	*	5
2017	Murphy (178)	*	*	*	*	**	*	*	*	9
2017	Pritchard (128)	*	*	*	*	-	*	*	*	7
2017	Yahya (201)	*	*	*	*	-	*	*	*	7
2018	Al-Omaishi (136)	*	*	-	*	**	-	*	*	7
2018	Bazzi (51)	*	*	*	*	**	*	*	*	9
2017	Dickfos (42)	*	*	-	*	-	-	*	*	5
2018	Guy (388)	*	*	*	*	-	*	*	*	7
2018	Krutsri (43)	*	*	*	*	-	*	*	*	7
2018	Mathur (41)	*	*	*	*	**	*	*	*	9
2018	McGrath (205)	*	*	-	*	**	-	*	*	7
2019	Abahuje (44)	*	*	*	*	**	*	*	*	9
2019	Cralley (137)	*	*	-	*	-	-	*	*	5
2019	Cunningham (151)	-	-	-	*	-	-	*	*	3
2019	Hx (188)	*	*	-	*	**	-	*	*	7
2019	Kinnear (153)	*	*	*	*	**	*	*	*	9
2019	Luo (138)	*	*	-	*	**	-	*	*	7
2020	Goh (139)	*	*	-	*	**		*	*	7
2020	Sarmiento (76)	*	*	*	*	-	*	*	*	7

Studies scoring 0-5, 6-7 and 8-9 points were identified as high, medium and low risk of bias, respectively. * indicates one point; ** indicates two points.

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