TITLE PAGE

Seasonality in surgical outcome data: A systematic review of the literature

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ABSTRACT

Background

Seasonal trends in patient outcomes are an under-researched area in perioperative care. This systematic review evaluates the published literature on seasonal variation in surgical outcomes worldwide.

Methods

MEDLINE, Embase, Cochrane, CINHAL, and Web of Science were searched for studies on major surgical procedures, examining mortality or other patient-relevant outcomes, across seasonal periods up to February 2019. Major surgery was defined as a procedure requiring an overnight stay in an inpatient medical facility. We included studies exploring variation according to calendar and meteorological seasons as well as recurring annual events including staff turnover. Quality was assessed using an adapted Downs & Blacks scoring system.

Results

The literature search identified 82 studies, including 22 210 299 patients from four continents. Due to the heterogeneity of reported outcomes and literature scope, a narrative synthesis was undertaken. Mass staff changeover was investigated in 37 studies; the majority (22) of these did not show strong evidence of worse outcomes. Of the 47 studies that examined outcomes across meteorological or calendar seasons, 33 found evidence of seasonal variation. Outcomes were often worse in winter (16 studies). This trend was particularly prominent amongst surgical procedures classed as an ‘emergency’ (5 of 9 studies). There was evidence for increased post-operative surgical site infections during summer (7 of 12 studies examining this concept).

Conclusion

This systematic review provides tentative evidence for an increased risk of post-operative surgical site infections in summer, an increased risk of worse outcomes after emergency surgery in winter and during staff changeover times.

INTRODUCTION

Seasonal trends in morbidity and mortality in healthcare have generated widespread interest in the media and scientific literature. Traditionally seasonality research focuses on calendar months or meteorological conditions and their relationship with healthcare outcomes. (1-3) However 'seasonality' can be conceptualised more broadly to include events or time periods occurring in a regular cycle which may affect healthcare delivery; these might include staff turnover dates, public holidays and reoccurring periods of increased demand on services, such as winter in some countries. (4, 5)

The most extensively researched period in the surgical literature is staff changeover at the beginning of each academic year, associated with an influx of new, less experienced middle grade medical staff. This change in personnel occurs during the summer months in American and British hospitals, coinciding with the time of year when senior staff are more likely to be on holiday. These combined factors are hypothesised to result in what is called the 'July effect' in the US, or 'August effect' in the UK, characterised by worse patient outcomes and an increase in medical errors. (6, 7)

Research into seasonal outcomes extends beyond this and includes investigating the impact of meteorological conditions as well as calendar seasons. For example, weather may directly affect the number, type and severity of presenting pathology, as well as complications of treatment. (8-10) An example is the 'winter pressures' period described predominantly in the UK, where colder weather is indirectly linked to worse outcomes because of increased pressure on hospital services associated with higher numbers of urgent and emergency care admissions. (11-13)

To date there is little certainty about the relationship between seasonal variation and surgical outcomes. A single systematic review examines the July effect, but there is a lack of research addressing the effect of 'seasonality' as a broader concept in perioperative care. (14) The topic presents challenges, as the potential causes for any seasonal variation are likely to be multifactorial. Furthermore, the observational datasets used by necessity in this field make it challenging to come to conclusions on causality. (1)

In order to provide a comprehensive overview, this review includes studies examining how seasonal variation affects outcomes following major surgery across several different countries and surgical specialities.

Our overall objective was to answer the following research question: is there evidence for variation in postoperative outcomes across the year, and if so, what characterises time periods in which postoperative outcomes are significantly affected – meteorological conditions, staff turnover or other factors? Furthermore, we evaluated seasonal variation in surgical outcomes across different categories of surgical urgency (emergency versus elective). Finally, we went on to critically analyse the quality of data in seasonal outcome research, with particular regards to adjustment for patient co-morbidities and clinical acuity of cases in each seasonal period.

METHODS

The protocol for this systematic review was registered prospectively with PROSPERO (registration: CRD42019137214). The study followed the PRISMA guidelines. (15)

Literature search

The following databases were searched: MEDLINE, Embase, Cochrane, CINHAL, and Web of Science. The results were imported into reference management software (Endnote X9). For each search, the entire database was explored up to 22nd February 2019, with no further date limits or language restrictions applied.

We also searched the grey literature to identify evidence published outside peer reviewed journals. This involved searching NHS Evidence, ProQuest Global Thesis Database, Health Management Information Consortium, DART Europe, Opengrey, ETHOS, and the New York Academy of Medicine Grey Literature Report. The full search strategy and its adaptations for different databases is detailed in appendix 1.

Definitions

Major surgery: a procedure requiring an overnight stay in an inpatient medical facility, and thus excluding day-case surgery. We excluded procedures performed by dentists, medical doctors (notably interventional cardiologists and gastroenterologists) and radiologists. Procedures for diagnostic purposes were also excluded (for example biopsy attainment, diagnostic laparoscopy and hysteroscopy). These definitions are similar to those used in previous studies. (16, 17)

We went on to detail three types of seasons, notably academic (periods of changeover from more to less experienced staff occurring annually) meteorological (e.g. temperature, sunlight hours, rainfall) and calendar (months of the year) season.

Outcomes: we focused on clinically important and patient-relevant endpoints, agreed by the research group and similar to other literature in this area. (18) These were subdivided into mortality, morbidity and efficiency outcomes for purpose of analysis (see appendix 2). Examples of outcomes which were not felt to be 'patient relevant' included; histological results, plasma vitamin D levels and some institutional efficiency factors including bed occupancy and wait list time.

Study selection

Inclusion and exclusion criteria & definitions

We included studies that describe patient relevant outcomes after a major surgical procedure according to a measure of seasonality (academic, calendar, meteorological).

We excluded studies if they analysed only the seasonal incidence of a disease requiring surgical intervention or surgical procedure (e.g. appendicitis), but not the outcomes of such diseases or procedures (e.g. mortality after appendicectomy). Furthermore, we did not consider studies where the measure of season was taken at the time of outcome, and not the time of surgery.

A tabulated summary of exclusion criteria can be found in appendix 3.

The primary reviewer (ES) screened all titles and abstracts. The secondary reviewer (MB) independently analysed 15% of all papers to check for agreement. Any disagreement was discussed, and a third reviewer was consulted if required. The reference lists of all studies meeting inclusion criteria was then examined in order to identify any additional articles not found during the initial search. This process was repeated until no further articles were found.

Quality assessment

Quality assessment of included studies was carried out using the Down's and Black's quality assessment checklist. (19) This was informed by other quality assessment tools including the STROBE checklist, which formalise reporting standards for observational studies. (20). We then adapted the checklist to suit our body of research. The original Downs and Black checklist awards incremental scoring for increased sample size. Many of our studies used large databases and therefore by default had large sample sizes. Instead we awarded a point for acknowledgement of a power calculation being carried out. We included an additional question to ensure funding sources had been declared. The edited checklist (see appendix 4) has a total possible score of 29 compared to 32 in the original version. We have grouped studies into poor (score <14), fair (15-19), good (20-25) and excellent (26-29) according to quality assessment score as is commonplace in the literature. (21)

The quality rating scores of the first reviewer (ES) were reviewed by another reviewer (MB), and discrepancies were resolved in a consensus meeting.

Data extraction

Data were extracted and presented in tables. Study characteristics extracted included the type of study, the data collection method, any adjustment for confounding, seasonality/time point measures, the urgency of surgery, and outcomes measures including effect sizes of various descriptive statistical analyses.

To further understand the quality of studies, we considered whether analysis had adjusted for patient factors. We recorded this as an adjustment for 'acute clinical status' (relating to the severity of the patient's illness at presentation) or 'chronic co-morbidities' (measures of the patient's baseline health). A full definition of these categories and a list of adjustments included in each are found in appendix 5.

Data analysis and synthesis of the results

Where possible, we extracted data on both the magnitude and the statistical significance of seasonal effects on outcome measures. The agreed definitions of statistical significance by the research group were 95 per cent confidence intervals which do not include 1 for data presented as risk ratios, odds ratios and hazard ratios; and a p-value of <0.05 for data presented as differences in means/proportions, mortality rates, correlation or regression coefficients. Some papers lack details of statistical calculations or P values and this has been noted in the data extraction tables.

We considered a meta-analysis but the heterogeneity of study designs, countries, climatic regions, and outcome measures reported meant that this was not possible. Therefore, we report a narrative description of our findings.

RESULTS

Identification of studies

After removing duplicate results, we were left with 17 329 records. After screening both title and abstracts, 350 records were found to be relevant for full paper review. Following full paper review and quality assessment 82 studies were included in the qualitative analysis. Papers were counted as separate studies if they used different definition of season, despite using the same cohort of patients. (22, 23)

See PRISMA flowchart in Figure 1.

Quality assessment

Eighty-four studies were quality assessed. The range of quality assessment scores for the studies was between 9 and 21.

Twenty-three studies were classified as poor (scoring <14), 49 studies as fair (15-19) and 12 studies as good (20-25). There were no studies classed as excellent (scoring >25). The score for all studies is available in appendix 6

We excluded two studies from the main analysis following a consensus decision. Both papers were deemed to have significant flaws in their methodology and were of insufficient quality. A description of these two studies can be found in appendix 7.

Studies generally described objectives, cohort characteristics, outcome measures and their findings clearly. Most were considered generalizable, reflecting that many were multi-centre cohort studies, in some cases using data from national databases.

Studies universally scored poorly in categories regarding participants ‘lost to follow up’; often studies did not acknowledge that there were patients in which outcome data was not recorded and did not describe the characteristics of this patient group. Forty-nine percent of studies had a defined time period during which outcome data was collected, or adjusted for a difference in time period for outcome data collection. Confounding factors were adjusted for in 49 studies, 58%.

Characteristics of the included studies

We included 82 studies in our systematic review. Each article is described in detail in appendix 8.

The studies meeting inclusion criteria were published between 1953 and 2019, totalling 22 210 299 patients. (Table 1)

Most of the research into seasonality and surgical outcomes was published in the most recent ten years of our observation period, with 61 studies (74%) published between 2010 and 2019. Sixteen papers were published between 2000-2009 (20%), and five (6%) before 2000.

Forty-six studies (56%) used traditional calendar months or meteorological season as their measure of seasonality. The remainder used academic season.

The majority of the studies report on patients in North America (53 studies, 65%). Fourteen studies (17%) referred to Europe (apart from the UK) and 10 to Asia (12%). Four studies (5%) were based in the United Kingdom, and one in Australia (1 study, 1%). Our search did not identify relevant studies from Latin America or Africa.

The literature covers a wide range of surgical specialities, with most studies being in trauma and orthopaedic surgery (22 studies, 27%), cardiothoracic surgery (12 studies, 15%) and spinal surgery (9 studies, 11%). Studies that included heterogeneous surgical populations were classified separately (12 studies, 15%).

Thirty-five studies (43%) examined elective surgery and 13 studies (16%) emergency surgery. Thirty two studies (39%) examined both. In the remaining two studies the surgical urgency was unclear.

Most studies were retrospective cohort studies (70 studies, 86%). Ten studies collected data prospectively (12%). There were two case-control studies (2%).

Most studies used data from multiple hospitals (51 studies, 61%), with the remainder collecting data from single centres (30 studies, 37%). There was one multinational study.

The large, multi-centre retrospective cohort studies used national healthcare databases, particularly in North America, where these are well established repositories of information. The National Inpatient Survey (NIS), a publicly available all-payer inpatient health care database in the United States, was used in 15 studies (18%). (24). The second most widely used database was the National Surgical Quality Improvement Programme (NSQIP), curated by the American College of Surgeons (used in 13 studies, 16%). (25)

Table 1 - Characteristics of Included Studies

Note – studies may examine more than one seasonal measure

	Number of Studies	Percentage of Studies	Number of Patients	Percentage of Patients
Total				
	82	100%	22 210 299	100%
Publication Date Range				
Pre 2000	5	6%	29 122	<1%
2000-2009	16	20%	936 123	4%
2010-2019	61	74%	21 245 054	96%
Location				
Asia	10	12%	95 005	<1%
Australia	1	1%	219 983	<1%
North America	53	65%	11 969 750	54%
Rest of Europe	14	17%	9 889 979	45%
UK	4	5%	35 582	<1%
Surgery Type				
Abdominal	6	7%	5 435 565	24%
Bariatric	2	2%	1 001 456	5%
Cardiothoracic	12	15%	1 467 120	7%
ENT	3	4%	8 585	<1%
Gynaecology	1	1%	1 136	<1%
Head & Neck	2	2%	48 848	<1%
Mixed	12	15%	11 146 650	50%
Neurosurgery	5	6%	59 574	<1%
Plastic	3	4%	14 403	<1%
Spinal Surgery	9	11%	156 208	<1%
Trauma & Orthopaedic	22	27%	2 330 955	10%
Transplant	3	4%	275 174	1%
Urology	1	1%	251	<1%
Vascular	1	1%	264 374	1%
Surgical Urgency				
Emergency	13	16%	1 573 688	7%
Elective	35	43%	13 012 814	59%
Covers Both	32	39%	7 622 044	34%
Unclear	2	2%	1 753	<1%
Seasonality Measure				
Academic	37	45%	3 319 340	15%
Calendar/Meteorological	47	57%	19 000 949	86%
Study Type				
Case-control	2	3%	1 311 773	6%
Prospective cohort	10	12%	55 614	<1%
Retrospective cohort	70	85%	20 842 912	94%
Data Collection Method				
Multinational centres	1	1%	737	<1%
Multi-centre (single country)	51	62%	21 836 718	98%
Single-centre	30	37%	372 844	2%

Evidence for seasonal variation in surgical outcomes

Association of academic season with surgical outcome

Thirty-seven studies examined 'academic season' (Table 2). Studies in this area were most commonly large North American (n= 34 studies) multicentre studies using national databases (n=29 studies). The timing of personnel changeover varied across countries, e.g. July in the United States, August in the United Kingdom, and February in Australia; however the principle of entire staff cohort changeover remained the same.

North American studies

Of the 34 studies set in North America, 17 studies conducted a July versus 'rest of the year' analysis, whilst the remaining 17 split the academic year into quarters and compare these. 15 showed at least one outcome that is worse after staff changeover in July or the 'July effect'. Among the 4 studies which found statistical significance when examining mortality the observed odds ratios ranged from a 1.14 times to 2.00 times increase in odds of mortality at academic changeover compared to the rest of the year. There was a larger range of effect sizes among the 13 studies which found statistical significance with morbidity measures. Odds ratios ranged from 1.03 times up to 4.55 increased in odds of morbidity at academic changeover compared to the rest of the year. In the later study confidence intervals were wide (CI 1.27 to 16.23), perhaps due to a relatively small sample size. (26)

The remaining 19 were not supportive of significantly different outcomes during staff changeover periods compared to the rest of the year. No study concluded that overall outcomes were improved in association with academic season.

Studies in the rest of the world

The three studies conducted outside of North America (2 in Asia and 1 multinational) did not find evidence for an association of outcomes with academic season.

Table 2 – Summary of Studies examining association between surgical outcomes and academic season, including D&B quality scoring.

Note - Studies may appear more than once in the table.

		Mortality	Morbidity	Efficiency	All Outcomes
	Number of studies	**25**	**35**	**20**	**37**
No. of distinct outcome measures per study	Range	1-2	1-5	1-3	1-7
	Median	1	2	2	4
Studies showing at least one outcome with seasonal association	Number of studies	4 (all North American)	13 (all North American)	3 (all North American)	15 (all North American)
	Number adjusting for chronic co-morbidities	4	9	3	
	Number adjusting for acute clinical status	1	2	1	
Studies showing no effect	Number of studies	21 (all North American)	22 (North America: 19, Asia: 2, Multinational: 1)	17 (North America: 15, Asia: 2)	22 (North America: 19, Asia: 2, Multinational: 1)
	Number adjusting for chronic comorbidities	15	14	8	
	Number adjusting for acute clinical status	5	4	3	

Note: D&B Score for those studies showing seasonal association: mean = 17.1, median = 20, IQ range = 17-20.

D&B Score for those studies ***not*** showing seasonal association: mean = 17.45, median = 18, IQ range = 17-19.

<u>Association of calendar/meteorological season with surgical outcome</u>

Forty-seven studies evaluated surgical outcome by traditional calendar seasons (defined by months of the year) or meteorological season (using meteorological definitions e.g temperature). We found that meteorological season studies generally compared winter with summer, which while varying in timing geographically, held the same principle of opposing average temperatures and daylight hours. Of these studies 21 examined the association of calendar/meteorological seasons with mortality, 12 with efficiency and 37 with morbidity. Overall 21 of these studies were based in North America, 14 in Europe, seven in Asia, four in the UK and one in Australia.

A detailed description of each study is in appendix 8. A summary can be found in Table 3.

Thirty-three of 47 studies found evidence for an association of at least one surgical outcome with calendar or meteorological season. In those which did, winter was most commonly associated with worse outcome (n=16 studies). However it is notable that summer was associated with worse outcome in another 12 studies.

There was a large range of effect sizes, in some cases very small in both studies showing worse outcomes in winter and summer. Odds ratios ranged from 1.01 to 2.87 times increased odds of worse outcomes in the winter. This range was equally broad in studies that found an increased risk of worse outcome in summer (odds ratios 1.11 to 3.69).

Twelve studies specifically evaluated surgical site infections (SSIs). Of these seven found that SSIs were more common in summer (9, 27-32) and one study found increased incidence in winter. (33) The remaining four studies showed no significant seasonal association. (23, 34-36) The odds of SSIs in summer was estimated to be 1.11 – 2.69 times the rate in winter in these seven studies. One study showed 3.69 times increase in odds of SSI occurring in summer compared to winter, however this was small population of only 750 participants with an SSI rate of only 4.7% overall. (31)

Six studies examined other types of postoperative infections, for example urinary tract infection or pneumonia. Three found evidence that these were more common in winter (37-39), two studies found an association with another season (40, 41) and in the remaining study no significant association was shown. (42) In the three studies who found increased risk of post-operative infection in winter, the odds ratio was between 1.74 and 3.73 times as likely compared to summer.

Of the studies which found seasonal variation in post-operative infection rates, only five undertook any patient-level case-mix adjustment. This was similar amongst studies that did not find seasonal variation.

Table 3 – Summary of Studies examining association between surgical outcomes and calendar/meteorological season, including D&B quality scoring.

Note: SSI = Surgical Site Infection, OPI = Other Postoperative Infection

		Mortality	Morbidity	Efficiency	All Outcomes
	Number of studies	**21**	**37** *SSI=12 OPI=6*	**13**	**47**
Number of distinct outcome measures per study	Range	1-3	1-4	1-2	1-4
	Median	1	1	1	1
Studies showing at least one outcome with seasonal association	Number of studies	9	26	5	33
	Worse outcome in winter	*5*	*12* *SSI=1 OPI=3*	*3*	*16*
	Worse outcome in summer	*1*	*10* *SSI=7 OPI=1*	*2*	*12*
	Number adjusting for chronic co-morbidities	5	10	3	
	Number adjusting for acute clinical status	0	2	2	
Studies showing no association	Number of studies	12	11	7	14
	Number adjusting for chronic comorbidities	8	7	5	
	Number adjusting for acute clinical status	3	3	1	

D&B Score for those studies showing seasonal association: mean = 17.1, median = 20, IQ range = 17-20

D&B Score for those studies ***not*** showing seasonal association: mean = 17.5, median = 18, IQ range = 17-19

Studies exploring causes of seasonal variation

Within the 47 studies examining the effect of calendar or meteorological season on surgical outcome data, eight studies undertook exploratory analyses of potentially causal associations (table 4).

The association of surgical urgency with seasonal variations in outcome

Emergency procedures alone were examined in 13 studies; four of these examined outcomes across academic season and nine across calendar or meteorological season. 32 studies examined heterogeneous cohorts including both emergency and elective procedures. In two studies classification of urgency was unclear. Studies were allocated into one of four groups depending on the urgency of surgical procedures examined. These groups included 'elective', 'emergency', 'covers both' and 'unknown'. This was in line with the NCEPOD definitions of immediate, urgent and expedited surgery. (43)

When the outcomes of emergency procedures across calendar season or meteorological conditions were examined, five out of nine studies (44-48) found worse outcomes in the winter. The odds ratios in this group ranged from 1.04 to 2.00. A single study (30) showed worse outcomes in the summer (odds ratio 1.98). The remaining three found no association.

Of the studies showing worse emergency surgery outcomes in winter, none adjusted for acute clinical status of the patient and three (44, 46, 48) adjusted for chronic co-morbidity. In those examining calendar season alone, defined by month of the year, meteorological conditions were not adjusted for.

Elective procedures alone were evaluated in 35 studies. Of these studies 15 examined outcomes across academic season and 20 across calendar or meteorological season. Of those 20 studies, 16 found an outcome associated with season. Only 6 studies showed worse outcomes in the winter, with odds ratios ranging from 1.27 to 3.73. The remaining 11 showing worse outcome in summer (odds ratios 1.93 to 3.69).

Table 4 – Causes for Seasonal Variation in Surgical Outcomes – Themes Examined

Paper	**Location of Study**	**Patient group and surgical intervention**	**Primary Conclusion**	**Explanatory Factors Examined**
Theme – Seasonality of increased demand on healthcare systems				
Chiu et al. (40)	Hong Kong,	Elderly patients (>60 years) undergoing emergency surgical repair of hip fractures	Increase in morbidity in winter months (22.8% of cases) compared to summer months (15.4% of cases). P<0.001	Winter months had a higher incidence of hip fractures (mean average +/- SD = 28.8 +/- 5.0) compared to summer months (mean average +/- SD = 20.9 +/- 6.0)
Yee et al. (41)	Hong Kong	Elderly patients (>65 years) undergoing emergency surgical repair of hip fractures	Increased risk of mortality in winter compared with summer (HR 1.040 95% CI 1.010-1.072) P=0.009	Significantly longer time-to-theatre for admission in the winter (mean days 3.17 +/- 3.6) compared with summer (mean days 3.08 +/- 3.46) P=0.027. Longer time to theatre associated with an increased risk of mortality (HR 1.018 95% CI 1.015-1.020) P<0.0001.
Theme – Seasonality of resource availability in healthcare systems				
Caillet et al. (42)	France	All adults (>18 years) undergoing open surgery in France	August found to be associated with an increased risk of mortality (OR 1.16, 95% CI 1.12-1.19) P<0.001.	Incidence of staff holiday higher in August (43% 95% CI 38.9-47.2) compared to other months (7.3% 95% CI 4.6 -10.1) P<0.001. August mortality increase only seen in those centres with activity reduction *[defined by volume of observed inpatient stays being significantly less than volume of expected stays]* (OR 1.15-1.36), P<0.001 but not in those without activity reduction (OR 1.06 95% CI 0.97-1.16)
Mundi et al. (43)	Canada	Patients with a diagnosis of oral squamous cell carcinoma treated with primary surgery.	Patient's operated in a month with >10% reduction in available operation room hours (July/August/September) had an increased risk of disease reoccurrence and death. (HR 1.59 95% CI 1.10 – 2.30) P=0.014.	Increased odds of waiting greater >28 days for operation if initial consultation in June/July/August. (OR 3.07 95% CI 1.96 – 4.81) P<0.001

Theme – Seasonality in causes of mortality and morbidity				
Eskedal et al. (44)	United Kingdom	Children (>2 months of age) undergoing open or closed cardiac surgery for structural congenital defects.	Late (>30 days postoperative) deaths are more common in winter [Nov to April] (70%) compared to summer [May to Oct] (30%). (P>0.001)	Cause of death more likely to be viral respiratory infection if death occurred in winter compared to summer (OR 17.3 95% CI 2.2-137). P<0.01
Durkin et al. (23)	North America	All patients undergoing spinal surgery	Increased risk of surgical site infection in summer compared to rest of the year RR 1.29 (1.09-1.52) P=0.003	Prevalence of gram positive cocci infection higher in summer than in winter (RR1.27 95% CI 1.06-1.52) P=0.008. No seasonal variation see in gram negative rods (RR 0.92 95% CI 0.62-1.35) P=0.47.
Durkin et al.	North America	All patients undergoing 15 most common surgical procedures	Increased risk of surgical site infection in summer compared to rest of the year RR 1.11 (1.10-1.12) P<0.001	Prevalence of both gram-positive cocci infection (RR, 1.09 95% CI, 1.00–1.19) P =0.04 and gram-negative bacilli (RR 1.24 95% CI 1.10–1.40) P < 0.001 higher in the summer.

DISCUSSION

This systematic literature review evaluated seasonal variation in outcomes in patients undergoing major surgery. Our review has mostly aggregative aims (describing what research has found with respect to academic, meteorological, and calendar season), but we have added elements of configurative exploration in order to look into causes for these described associations. (49)

We found weak evidence for an association between academic season and outcomes after major surgery: 15 out of 37 studies which evaluated this factor found evidence of worse outcomes during periods of staff turnover. These studies were of marginally better quality than those finding no association.

We found some support for the notion of a 'winter effect' seen in healthcare systems. Increased mortality from medical conditions is known to occur with colder temperatures, and is thought to predominantly affect the elderly. (8, 50-53) To date there has been much less focus on whether this also occurs in surgical patients. (1, 54-56). Conversely, a number of studies reported worse surgical outcome in summer months. It is possible that meteorological or seasonal analysis was confounded by academic season, as in all countries where this was evaluated, mass staff turnover tended to be in the summer. Our findings also lend further support to the established consensus that SSIs are hypothesised to be associated with higher temperatures. (57, 58)

Explanatory factors

Given the lack of previous investigation into surgical outcomes across seasons, it is interesting to hypothesize which factors may contribute to this effect. Although the contribution of staff turnover to seasonal variation in quality of care is well examined, this review has shown that research on other potential explanatory factors is sparse.

One such hypothesis is that fluctuations in staffing levels throughout the year due to either illness or holiday may affect the quality of care. The Caillet et al. study showed that a peak in staff holiday was mirrored by a peak in surgical mortality in the month of August. This large population based study set in France showed that this association was only seen in centres where hospital activity decreased in line with staff leave. (59) In addition studies have shown that low nurse to patient ratios increased mortality. (60) Although there is not distinct annual period of nursing staff turnover, studies have found that low nurse to patient ratios are more common in winter. (61) It is not easy to determine if this is due to higher patient numbers or increased nursing shortages, perhaps due to seasonal variation in staff sickness.

Patient outcomes may also be affected when the demand for services exceeds capacity. Recent international experience with the COVID19 pandemic has seen some health systems come close to being overwhelmed by a sudden increase in demand for emergency, medical, respiratory and critical care services. In many centres, this necessitated a reduction in elective activity in order to manage this demand safely. (62) The UK's annual data shows that winter months are associated with an increase in presentations to emergency departments. (63) This trend is replicated globally, even in countries that experience milder winters (64, 65). One example where this increased demand is hypothesised to cause worse outcomes is emergency repair of hip fractures, as demonstrated by increased morbidity and mortality in winter. (46, 47)

Such variations in capacity will have downstream effects on the way hospital processes function, which will affect patient outcomes. One measure of this examined in our review is the concept of delayed 'time to operating theatre' with an increased number of hip fracture presentations. In the Yee et al. analysis this delay to theatre was associated with increased mortality. (46)

We can also postulate that seasonal variation in surgical outcomes may be due to patient factors rather than system level factors. For example there is evidence that surgical pathologies that predispose to SSI occur more commonly in summer months, such as trauma presentations. (9).

The type and complexity of patients may also vary seasonally. Vulnerable population groups, such as the elderly and those with underlying medical conditions, are thought to be more at risk of winter time mortality and morbidity. (8, 50, 54) One contributing factor is an increase in cardiovascular, thrombotic and respiratory illness in winter, all of which are more common in the elderly. (54)

Seasonal viral and bacterial infections, such as influenza and norovirus, cause staff sickness and significant morbidity to patients. These have historically been linked to excess winter deaths and infections are a parameter closely monitored by health authorities to predict winter mortality (52, 66, 67). Eskedal et al. found that in paediatric surgery viral respiratory conditions were a more common cause of postoperative death in winter than summer. (68) Also, concerning SSIs, one common skin pathogen, *staphylococcus aureus,* is known to both colonise human skin, and cause soft tissue infection more commonly with warm temperatures. (69, 70)

Limitations and strengths of this review

We analysed the quality of research in this field, particularly regarding adjustment for individual patient co-morbidity and clinical acuity of cases. We have demonstrated throughout our review that chronic co-morbidities of individual patients are adjusted for in the majority of studies. However, most studies failed to adjust for the patients' acute clinical status on the day of surgery which is a potential confounder, particularly in emergency surgery.

Given that all studies we reviewed are observational, and generally none were preregistered, we cannot rule out publication bias. Investigations that identify seasonal differences may be more likely to reach publication and therefore appear in our review than investigations with 'null findings'. We were not able to formally assess the likelihood or extent of publication bias in this review.

The heterogeneity of studies limited the analysis of this literature. Multiple dissimilar definitions of season were analysed, and within these definitions the reviewed studies differed in their categorisation schemes. Beyond this there were different definitions for outcomes, different surgical cohorts and different categories of surgical urgency. This made the data set unsuitable for meta-analysis, and also presented a challenge narratively comparing studies and drawing conclusions from the literature field as a whole. However this challenge does not undermine the importance of examining this research area. The COVID 19 pandemic has highlighted how extreme service pressures can effect perioperative services and outcomes. To understand seasonal service pressures, even on a smaller scale, will help target interventions which will reduce the impact on clinical standards of care.

Implications for future research

Having identified the potential for both staff turnover periods and the winter season to impact patient outcomes adversely, the imperative now is to evaluate potential mitigations. For this, we need to understand better the underpinning reasons for these differences in the outcome – in the winter, for example, how much is attributable to patient factors (such as risk of concomitant respiratory infections) and how much to hospital structures and processes (such as access to postoperative critical care). Understanding this will help determine interventions that can be tested in trials or service evaluations, such as increasing ring-fenced access to enhanced or critical care beds after surgery, or avoiding truly elective surgery in the most vulnerable patients during the winter season. Medical or technical interventions to reduce surgical site infection in summer months may also be a future innovation opportunity.

Conclusions

In conclusion, we have found limited evidence to support both an adverse winter effect on surgical outcome, particularly in emergency surgery, and a staff turnover effect during the summer months. There was also evidence that surgical site infections are more common in warmer weather. Overall the quality of evidence was poor or moderate, and would be improved by better attention to patient-level case-mix adjustment. This review highlights the need for more extensive research in this area. With quantification of seasonal variation in perioperative outcomes and identification of potentially modifiable contributory factors, system level innovations to reduce this phenomenon could be made.

Conflict of interest

The authors declare that they have no conflict of interest

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Data interpretation: PM, ARG, SRM
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