Seasonality in surgical outcome data: a systematic review and narrative synthesis

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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 and recurring annual events including staff turnover. Quality was assessed using an adapted Downs and Black scoring system.

Results: The literature search identified 82 studies, including 22,210,299 patients from four continents. Because of 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 ‘emergency’ (five of nine studies). There was evidence for increased postoperative surgical site infections during summer (seven of 12 studies examining this concept).

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

Clinical trial registration: PROSPERO CRD42019137214.

Keywords: July effect; perioperative outcomes; seasonality; seasonal variation; staff changeover; surgical outcomes; winter pressures

Editor’s key points

- In this systematic review, the authors examined the evidence for variation in patient outcomes after major surgery across the year and during recurring events such as public holidays.
- Periods of mass staff turnover and the winter months were found to be weakly associated with worse perioperative outcomes after major surgery, particularly if the surgery was unplanned.
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 USA, 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 and calendar seasons. For example, weather may directly affect the number, type, and severity of presenting pathology, and complications of treatment.5-10 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 after 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 vs 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 February 22, 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 are detailed in the Supplementary 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.17 These were subdivided into mortality, morbidity, and efficiency outcomes for purpose of analysis (see Supplementary 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 and 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 Supplementary 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 were 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 Downs and Black quality assessment checklist. This was informed by other quality assessment tools including the STROBE checklist, which formalise reporting standards for observational studies. 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 Supplementary Appendix 4) has a total possible score of 29 compared with 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.

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 Supplementary 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% 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. After full paper review and quality assessment, 82 studies were included in the qualitative analysis. Papers were counted as separate studies if they used different definitions of season, despite using the same cohort of patients. See the PRISMA flowchart in Fig. 1.

Quality assessment

Eighty-four studies were quality assessed. The range of quality assessment scores for the studies was between nine 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 classified as excellent (scoring >25). The score for all studies is available in the Supplementary Appendix 6.

We excluded two studies from the main analysis after 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 Supplementary Appendix 7.

Studies generally described objectives, cohort characteristics, outcome measures and their findings clearly. Most were considered generalisable, reflecting that many were multicentre 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 whom outcome data were 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 were 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 Supplementary 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 10 yr of our observation period, with 61 studies (74%) published between 2010 and 2019. Sixteen papers were published between 2000 and 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 UK, and one in Australia (one 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 (nine studies, 11%). Studies that included...
Records identified through database searching 23/2/19
  \( n = 22,388 \)
  - Medline \( n = 7,330 \)
  - Embase \( n = 10,473 \)
  - Cochrane \( n = 440 \)
  - CINHAL \( n = 2,042 \)
  - Web of Science \( n = 2,103 \)

Duplicates removed \( n = 5,438 \)
Records after duplicates removed \( n = 17,329 \)

Records screened for title \( n = 17,329 \)

Records excluded at title \( n = 16,508 \)

Records screened for abstract \( n = 821 \)

Records excluded at abstract \( n = 471 \)
- Duplicates identified \( n = 51 \)
- Irrelevant content \( n = 419 \)
- Unable to translate \( n = 1 \)

Full-text articles assessed for eligibility \( n = 350 \)

Identified from references/other reading \( n = 5 \)

Studies included in quality assessment \( n = 84 \)

Studies excluded because of exceptionally poor quality \( n = 2 \)

Full-text articles excluded, \( n = 271 \)
- Not peer-reviewed literature \( n = 99 \)
- Irrelevant content \( n = 156 \)
- Duplicate \( n = 13 \)
- Unable to translate \( n = 3 \)

Studies included in qualitative analysis \( n = 82 \)

Additional records identified through other sources 23/2/19
  \( n = 379 \)
- NHS Evidence \( n = 250 \)
- ProQuest Global Thesis Database \( n = 113 \)
- Health Management Information Consortium \( n = 15 \)
- DART Europe \( n = 1 \)
- Opengrey, ETHOS, New York Academy of Medicine Grey Literature Report \( n = 0 \)

Additional records identified through other sources 23/2/19
  \( n = 379 \)
- NHS Evidence \( n = 250 \)
- ProQuest Global Thesis Database \( n = 113 \)
- Health Management Information Consortium \( n = 15 \)
- DART Europe \( n = 1 \)
- Opengrey, ETHOS, New York Academy of Medicine Grey Literature Report \( n = 0 \)

Fig 1. PRISMA flow diagram.
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, multicentre 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 healthcare database in the USA, was used in 15 studies (18%). 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%).

### 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 USA, August in the UK, 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 vs ‘rest of the year’ analysis, whilst the remaining 17 split the academic year into quarters and compared these. A total of 15 showed at least one outcome that is worse after staff changeover in July or the ‘July effect’.

### Table 1 Characteristics of included studies. Note—studies may examine more than one seasonal measure. ENT, ear, nose and throat.

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<th>Percentage of studies</th>
<th>Number of patients</th>
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<tr>
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<td>62</td>
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<td>37</td>
<td>372 844</td>
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</table>
Among the four 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 with 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 times increase in odds of morbidity at academic changeover compared with the rest of the year. In the later study confidence intervals were wide (1.27–16.23), perhaps because of a relatively small sample size.

The remaining 19 were not supportive of significantly different outcomes during staff changeover periods compared with 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 (two in Asia and one multinational) did not find evidence for an association of outcomes with academic season.

Association of calendar/meteorological season with surgical outcome

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 Supplementary 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 1.11–3.69).

Twelve studies specifically evaluated surgical site infections (SSIs). Of these, seven found that SSIs were more common in summer 27–32 and one study found increased incidence in winter. 33 The remaining four studies showed no significant seasonal association. 34,35,36 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 a 3.69 times increase in odds of SSI occurring in summer compared with winter; however, this was a 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...
definitions of immediate, urgent, and expedited surgery. 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 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 six studies showed worse outcomes in the winter, with odds ratios ranging from 1.27 to 3.73. The remaining 11 showed worse outcome in summer (odds ratios 1.93–3.69).

**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.

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 older patients. 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

**Table 3 Summary of studies examining association between surgical outcomes and calendar/meteorological season, including Downs and Black quality scoring. Downs and Black score for those studies showing seasonal association: mean=17.1, median=18, inter-quartile range=17–20. Downs and Black score for those studies not showing seasonal association: mean=17.5, median=18, inter-quartile range = 17–19. OPI, other postoperative infection; SSI, surgical site infection.**

<table>
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<tr>
<th>Measure</th>
<th>Number of studies</th>
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<th>Mortality</th>
<th>Efficiency</th>
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<tr>
<td>Number adjusting for chronic co-morbidities</td>
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</table>

winter, two studies found an association with another season, and in the remaining study, no significant association was shown. In the three studies which found increased risk of postoperative infection in winter, the odds ratio was between 1.74 and 3.73 times as likely compared with summer.

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

**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 the academic season and nine across calendar or meteorological seasons. A total of 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 National Confidential Enquiry into Patient Outcome and Death (NCEPOD) definitions of immediate, urgent, and expedited surgery.

When the outcomes of emergency procedures across calendar season or meteorological conditions were examined, five out of nine studies found worse outcomes in the winter. The odds ratios in this group ranged from 1.04 to 2.00. A single study 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 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 six studies showed worse outcomes in the winter, with odds ratios ranging from 1.27 to 3.73. The remaining 11 showed worse outcome in summer (odds ratios 1.93–3.69).
**Table 4** Causes for seasonal variation in surgical outcomes – themes examined. CI, confidence interval; HR, hazard ratio; OR, odds ratio; RR, risk ratio; SD, standard deviation.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Location of study</th>
<th>Patient group and surgical intervention</th>
<th>Primary conclusion</th>
<th>Explanatory factors examined</th>
</tr>
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<tr>
<td>Theme — seasonality of increased demand on healthcare systems</td>
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<tr>
<td>Chiu and colleagues</td>
<td>Hong Kong</td>
<td>Older patients (&gt;60 yr) undergoing emergency surgical repair of hip fractures</td>
<td>Increase in morbidity in winter months (22.8% of cases) compared with summer months (15.4% of cases) ( P &lt; 0.001 )</td>
<td>Winter months had a higher incidence of hip fractures (mean average [SD] = 28.8 [5.0]) compared with summer months (mean average [SD] = 20.9 [6.0])</td>
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<tr>
<td>Yee and colleagues</td>
<td>Hong Kong</td>
<td>Older patients (&gt;65 yr) undergoing emergency surgical repair of hip fractures</td>
<td>Increased risk of mortality in winter compared with summer (HR 1.040, 95% CI 1.010–1.072) ( P = 0.009 )</td>
<td>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 &lt; 0.0001 )</td>
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<tr>
<td>Theme — seasonality of resource availability in healthcare systems</td>
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<tr>
<td>Caillot and colleagues</td>
<td>France</td>
<td>All adults (&gt;18 yr) undergoing open surgery in France</td>
<td>August found to be associated with an increased risk of mortality (OR 1.16, 95% CI 1.12–1.19) ( P &lt; 0.001 )</td>
<td>Incidence of staff holiday higher in August (43%, 95% CI 38.9–47.2%) compared with other months (7.3%, 95% CI 4.6–10.1%) ( P &lt; 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 &lt; 0.001 ) but not in those without activity reduction (OR 1.06, 95% CI 0.97–1.16)</td>
</tr>
<tr>
<td>Mundi and colleagues</td>
<td>Canada</td>
<td>Patients with a diagnosis of oral squamous cell carcinoma treated with primary surgery</td>
<td>Patient’s operated in a month with &gt;10% reduction in available operation room hours (July/August/September) had an increased risk of disease recurrence and death (HR 1.59, 95% CI 1.10–2.30) ( P = 0.014 )</td>
<td>Increased odds of waiting &gt;28 days for operation if initial consultation in June/July/August. (OR 3.07, 95% CI 1.96–4.81) ( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Theme — seasonality in causes of mortality and morbidity</td>
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<tr>
<td>Eskedal and colleagues</td>
<td>UK</td>
<td>Children (&gt;2 months of age) undergoing open or closed cardiac surgery for structural congenital defects</td>
<td>Late (&gt;30 days postoperative) deaths are more common in winter (November to April) (70%) compared with summer (May to October) (30%) ( P &lt; 0.001 )</td>
<td>Cause of death more likely to be viral respiratory infection if death occurred in winter compared with summer (OR 17.3, 95% CI 2.2–137) ( P &lt; 0.01 )</td>
</tr>
<tr>
<td>Durkin and colleagues</td>
<td>North America</td>
<td>All patients undergoing spinal surgery</td>
<td>Increased risk of surgical site infection in summer compared with rest of the year RR 1.29 (1.09–1.52) ( P = 0.003 )</td>
<td>Prevalence of gram-positive cocci infection higher in summer than in winter (RR 1.27, 95% CI 1.06–1.52) ( P = 0.008 ). No seasonal variation see in</td>
</tr>
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</table>
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 hypothesise 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, because of either illness or holiday, may affect the quality of care. The study of Caillet and colleagues59 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 a 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 because of higher patient numbers or increased nursing shortages, perhaps because of seasonal variation in staff sickness.

Patient outcomes may also be affected when the demand for services exceeds capacity. Recent international experience with the COVID-19 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 show 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 analysis by Yee and colleagues,46 this delay to theatre was associated with increased mortality.

We can also postulate that seasonal variation in surgical outcomes may be because of patient factors rather than system level factors. For example, there is evidence that surgical pathologies that predispose to SSIs occur more commonly in summer months, such as trauma presentations.7

The type and complexity of patients may also vary seasonally. Vulnerable population groups, such as older patients and those with underlying medical conditions, are thought to be more at risk of wintertime mortality and morbidity.50,54 One contributing factor is an increase in cardiovascular, thrombotic, and respiratory illness in winter, all of which are more common in older patients.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.\textsuperscript{52,66,67} Eskedal and colleagues\textsuperscript{18} found that in paediatric surgery, viral respiratory conditions were a more common cause of postoperative death in winter than summer. 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.\textsuperscript{59,70}

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. Identifications 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 affect 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 SSIs 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 SSIs are more common in warmer weather. Overall, the quality of evidence was poor or moderate, and it would have been 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.

Authors’ contributions

Conception of systematic review: ES, MB, PM, SRM.
Design of systematic review: ES, MB, PM, SRM.
Supervision of review: SRM.
Literature search: ES, MB.
Data collection: ES, MB.
Data interpretation: PM, ARG, SRM.
Drafting of paper: ES.
Revision of paper for critical intellectual content: all authors.
Approval of final version: all authors.

Declarations of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2021.10.043.

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