The second victim – supporting JMOs through medical errors

Dr Sarah Newman, Assistant Director, Doctors' Health Advisory Service WA,
General Practice, MDA National Member

The term 'second victim', coined by Wu in 2000*, encapsulates the impact of medical error on clinicians. Despite public perception, and what hard-line medical culture would have us believe, medical error is inevitable as we are all fallibly human.

We accept the patient as the first victim, and our critical incident review process naturally focuses on their outcomes. But the health professionals who feel responsible can often be neglected.

Although linear root cause analyses attempt to appreciate the multifactorial reasons behind incidents where the individual is only one 'hole' in the 'Swiss Cheese' model, the emotional impact of errors may be overlooked. Doctors who are second victims may experience psychological distress, burnout, post-traumatic stress, risk-averse practice, and maladaptive behaviours including drug and alcohol abuse, leaving the profession and, in the worst case, suicide.

Junior doctors and trainees (JMOs) are particularly vulnerable to the effects of medical errors. Inexperience, high workload, increased fatigue, burnout, and feelings of inadequate clinical supervision are important contributors. Senior guidance is critical in shifting the perceptive from trauma to growth. Medical errors can be re-envisioned as formative learning experiences – for the second victim, their colleagues and the organisation.

Medical leadership sets the culture for how medical errors are viewed, processed and managed.

The work environment must be a safe place to discuss mistakes. Water-cooler gossip is harmful and should be actively discouraged. JMOs require support when providing open disclosure to the patient, and it helps to understand that admission and apology do not imply legal liability. They should be encouraged to have early discussions with their medical defence organisation to address medico-legal consequences.

1. **Assess any acute needs.**
   Second victims are often distressed immediately after the incident comes to light, needing a safe space for a sounding board and psychological first aid, while steering away from clinical scrutiny. The JMO may need a break or to go home. Disclosing one's own inevitable experience of medical errors normalises and validates their experience.
2. **Facilitate reflection to enable clinical growth.**
   Have regular check-ins with the JMO and make sure they know the existing hospital and external support available for further assistance. In times of crisis and distress, the Australasian Doctors' Health Network directs viewers or callers to the state based health organisations which provide 24/7 advice lines manned by medical practitioners experienced in doctors' health. These organisations can support doctors acutely, anonymously, and with confidentiality.

Systemic change is needed when approaching medical error. When the second victim is blamed, the healthcare organisation and patients suffer. Consider what simple interventions in everyday practices could prevent future second victims, and integrate early and ongoing support for second victims into the workplace.

Open discussion of medical errors during college education, peer groups and supervision will help dispel the stigma of mistakes. At the end of the day, we are all only human. A human response of empathetic support helps JMOs become better clinicians, moving forward from 'victim' to formulating meaning and experience after medical error.

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*Reference available on request: marketing@mdanational.com.au

REVIEW ARTICLE

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Association between higher ambient temperature and orthopaedic infection rates: a systematic review and meta-analysis

Mark L. Vickers[*,†] Anita Pelecanos[‡] Marie Tran[†] Lars Eriksson[§] Mohamad Assoum[¶] Patrick N. Harris[†,||,**] Anjali Jaiprakash[††] Benjamin Parkinson[‡‡,§§] Joel Dulhunty[¶¶,||||] and Ross W. Crawford[****]

*Biomedical Engineering and Clinical Sciences, Queensland University of Technology, Brisbane, Queensland, Australia
†Faculty of Medicine, The University of Queensland, Brisbane, Queensland, Australia
‡QIMR Berghofer Medical Research Institute, Brisbane, Queensland, Australia
§Herston Health Sciences Library, The University of Queensland, Brisbane, Queensland, Australia
¶Centre for Child Health Research, The University of Queensland, Brisbane, Queensland, Australia
||Infection Management Services, Princess Alexandra Hospital, Brisbane, Queensland, Australia
**Pathology Queensland, Central Laboratory, Brisbane, Queensland, Australia
††Science and Engineering Faculty, Queensland University of Technology, Brisbane, Queensland, Australia
‡‡School of Medicine, James Cook University, Townsville, Queensland, Australia
§§Department of Orthopaedics, Cairns Base Hospital, Cairns, Queensland, Australia
¶¶UQ Centre for Clinical Research, The University of Queensland, Brisbane, Queensland, Australia
||||Research and Medical Education, Redcliffe Hospital, Brisbane, Queensland, Australia and
***Orthopaedics Department, The Prince Charles Hospital, Brisbane, Queensland, Australia

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Correspondence
Dr Mark L. Vickers, Biomedical Engineering and Clinical Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, QLD 4001, Australia.
Email: mark.vickers@uq.net.au

M. L. Vickers MD; **A. Pelecanos** BHSc; **M. Tran** MD; **L. Eriksson** BA; **M. Assoum** PhD; **P. N. Harris** PhD; **A. Jaiprakash** PhD; **B. Parkinson** MBBS; **J. Dulhunty** PhD; **R. W. Crawford** PhD.

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Abstract

Introduction: Many infectious diseases display seasonal variation corresponding with particular conditions. In orthopaedics a growing body of evidence has identified surges in post-operative infection rates during higher temperature periods. The aim of this research was to collate and synthesize the current literature on this topic.
Methods: A systematic review and meta-analysis was performed using five databases (PubMed, Embase, CINAHL, Web of Science and Central (Cochrane)). Study quality was assessed using the Grading of Recommendations Assessment, Development and Evaluation method. Odds ratios (ORs) were calculated from monthly infection rates and a pooled OR was generated using the DerSimonian and Lairds method. A protocol for this review was registered with the National Institute for Health Research International Prospective Register of Systematic Reviews (CRD42017081871).
Results: Eighteen studies analysing over 19 000 cases of orthopaedic related infection met inclusion criteria. Data on 6620 cases and 9035 controls from 12 studies were included for meta-analysis. The pooled OR indicated an overall increased odds of post-operative infection for patients undergoing orthopaedic procedures during warmer periods of the year (pooled OR 1.16, 95% confidence interval 1.04–1.30).
Conclusion: A small but significantly increased odds of post-operative infection may exist for orthopaedic patients who undergo procedures during higher temperature periods. It is hypothesized that this effect is geographically dependent and confounded by meteorological factors, local cultural variables and hospital staffing cycles.

Introduction

Seasonality is a feature of many infectious diseases of public health importance and is characterized by case number surges corresponding to predictable calendar periods or some other time related pattern.[1] Annual peaks in influenza, meningococcal disease and pneumonia are well known to result from a complex interplay between host, pathogen and environment with temperature, air quality and relative humidity playing a critical role.[2–4] Recently, a growing body of literature has come to suggest that post-operative orthopaedic infections may exhibit seasonal oscillations peaking at times of higher temperature.

The organisms of primary concern following orthopaedic surgery are commensal staphylococci, with rates of post-operative infection at 1–3% following elective surgery and as high as 55% after emergent procedures.[5–7] For patients, the impact of post-operative infection can be high, involving longer hospital stays, increased readmission, inflated healthcare costs, pain, functional loss, extended antibiotic use and repeat surgery.[7–12] Despite a great deal of prior research on risk factors for infection,[5,6,8–11,13] there has been no systematic review to date on the role of environmental temperature in orthopaedic post-operative infection. Identifying seasonal infection surges during the warmer months may help clinicians to improve patient outcomes by guiding approaches to wound care, infection surveillance, antibiotic choice and procedure timing. Therefore, we conducted a systematic review and meta-analysis to evaluate whether orthopaedic infections exhibit seasonality during the warmer calendar periods.

Methods

This systematic review is reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.[14] No ethical approval or patient consent was required. A protocol for this review was registered with the National Institute for Health Research International Prospective Register of Systematic Reviews 'PROSPERO' (CRD42017081871).

Search strategy

To identify research focusing on seasonal trends in orthopaedic infections we conducted a search of PubMed, Embase, CINAHL, Web of Science and Central (Cochrane) using the following search terms: temperature, seasonality, time of year, season, summer, spring, autumn, winter, rainfall, humidity, time series AND surgical wound infection, orthopaedic procedures/adverse effects, orthopaedics/adverse effects, surgical site infection, surgical wound infection, prosthesis-related infection, wound infection AND surgery, surgical, acetabuloplasty, arthrodesis, arthroplasty, arthroscopy, discectomy, fracture fixation, osteotomy, spinal surgery, laminectomy, internal fixation, joint, joint replacement, revision, lower limb, upper limb, hip, knee, shoulder, bone, bone graft, prosthetic, prosthetic joint, osteoplasty, chondroplasty, debridement AND infection. No date restrictions were applied. We excluded 'animal only' studies and non-English language documents. See Appendix S1 for the full search strategy.

Eligibility criteria

Two authors independently reviewed the search results in a three-step process that assessed for inclusion based on title, abstract and full text. An article was considered eligible if: (i) the study population were orthopaedic patients; (ii) the research sought to identify infection or readmission for infection as a primary or secondary outcome; and (iii) the factor of interest was seasonality. 'Cases' were defined as orthopaedic patients with a bone or surgical site infection. We defined infection using the Centers for Disease Control guidelines for osteomyelitis, disc space infection, joint or bursa infection, periprosthetic joint infection, soft tissue infection, superficial and deep surgical site infection.[15] Superficial surgical site infection is defined as occurring within 30 days following operation while deep surgical site infection is defined as occurring within 30 to 90 days.[15] Seasonality was defined as a surge in cases corresponding with predictable calendar periods or another factor across time.[1] We included all studies that analysed infection rates against calendar dates, humidity, temperature, rainfall or staff intake cycles. We excluded papers that looked at seasonality in chronic pre-operative infections such as chronic osteomyelitis or diabetic foot because the time of infection onset was difficult to determine.

Data extraction

A data extraction sheet was generated and refined during the full text review stage. Two authors extracted data on: study type, study aims or objectives, infection incidence rates, adjusted odds of infection, country of origin, date range, cohort size, data source, number of centres involved, patient inclusion criteria, organisms of interest, definition of season and infection, statistical methods, key findings, patient characteristics, clinical recommendations and study limitations.

Risk of bias

Two authors independently assessed for risk of bias using the Grading of Recommendations Assessment, Development and Evaluation method[16] for assessing the quality of observational studies. This was used in conjunction with the Cochrane Risk-of-Bias tool.[17] We assessed studies across three domains: (i) eligibility criteria; (ii) exposure and outcome measures; and (iii) control of confounding. Risk of bias tables was generated using Revman 5.[18]

Statistical analysis

The meta-analysis was performed with Stata version 15 (StataCorp, College Station, TX, USA). We included adjusted odds ratios (ORs) provided by study authors. Otherwise we calculated crude ORs from the infection numbers and rates provided. ORs were displayed using a forest plot and pooled using a random effects model and the DerSimonian and Lairds method. Heterogeneity estimates were derived using the Mantel Haenszel method. Study heterogeneity was assessed using the I^2 statistic with values of 25%, 50% and 75% resembling low, moderate and high levels of heterogeneity respectively. A funnel plot and Egger's test were used to assess risk of publication bias through small study effects.

Ethics approval was not required for this research as all data used was freely available in the public domain.

Results

Systematic review study characteristics

Our search identified 2191 unique documents. Eighteen studies met all criteria and were included in this review.[6–13,19–27] Figure 1 represents the process of inclusion and exclusion. Cumulatively, all the studies in this review analysed over 19 000 cases of orthopaedic

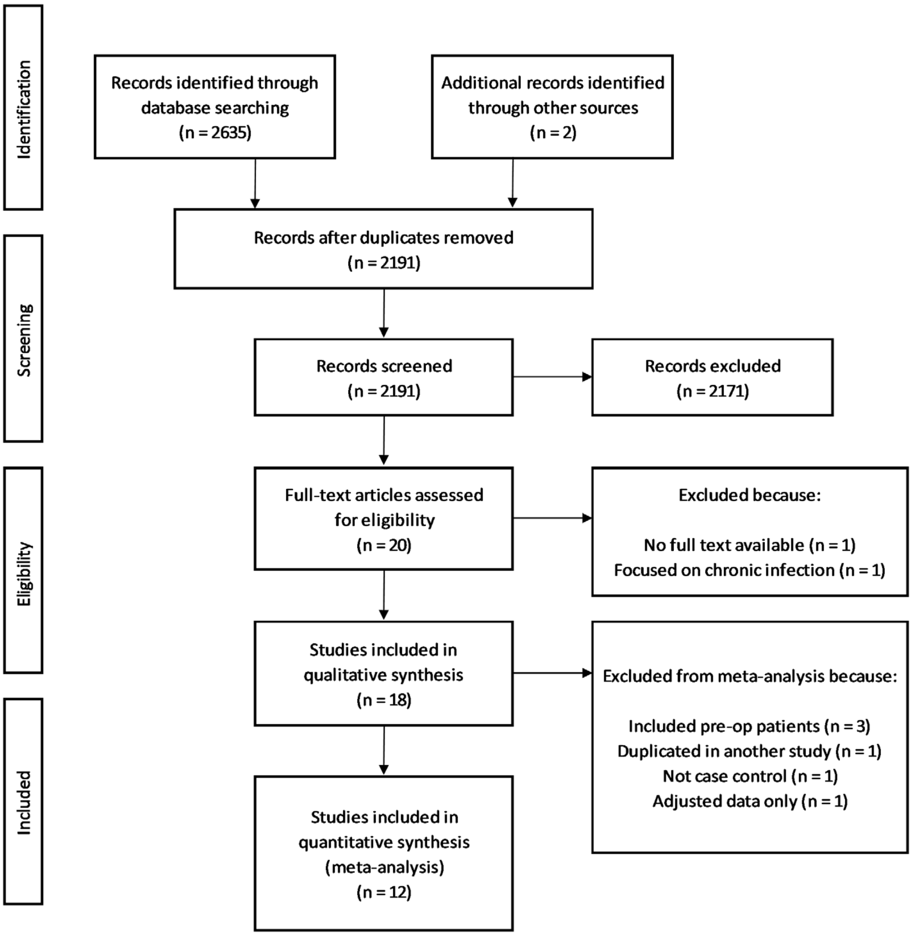


Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow chart and included studies.

infection from a total cohort of more than 2 100 000 patients. The study which analysed the highest number of cases was by McDonald *et al.* with 9128 infections.[24] Sixteen (89%) studies directly stated the number of infection cases[5–13,19–24,27] while case number was obtained from the authors for one manuscript (7%)[26] and could not be derived for one study.[25] Most research was carried out in the USA (14 studies, 78%)[5–11,13,19–21,23–25] while one study each was conducted in Taiwan,[22] Japan,[12] Australia[26] and Switzerland.[27] The Australian paper by Parkinson *et al.* was the only study conducted in the Southern Hemisphere.[26] A map showing geographic study origin and average land surface temperature for the region is shown in Figure 2. Land surface temperature varies widely from atmospheric temperature and was used to indicate comparison between international regions. The mean study length was 77.3 months (interquartile range 36–96). Six (33%) studies utilized national databases,[8,12,19,24–26] nine (50%) used data from a single site[5–7,10,11,20,22,23,27] and three (17%) were multi-site.[9,13,21] Spinal surgery patients were the most commonly studied population (7 papers, 39%)[6,9,10,12,21,24,25] followed by arthroplasty patients (4 papers, 22%).[8,11,19,26] Three (17%) papers included data on acute pre-operative infections[20,23,27] while the remaining analysed post-operative infections. Five (28%) of the studies included information on causative organisms.[5,9,13,23,27] A summary of key study characteristics are shown in Table 1 (complete details are listed in Appendix S2).

Meta-analysis odds of infection

There were 12 studies which provided data that could be pooled for meta-analysis.[6–13,21,22,24,26] We included results for a combined 6620 cases and 9035 controls. The pooled OR indicated an overall increased odds of post-operative infection for patients undergoing orthopaedic procedures during warmer periods of the year (pooled OR 1.16, 95% confidence interval (CI) 1.04–1.30). Of the six studies excluded from the meta-analysis, three included pre-operative infections in their dataset,[20,23,27] one presented data duplicated in another included study,[5] one did not provide sufficient information on case and control numbers[19] and one provided data adjusted for age and comorbidities.[25]

Eight (67%) of the included studies considered higher temperature periods by season or time of year[7–11,13,22,26] while four (33%) studies analysed seasonality in relation to junior doctor intake period.[6,12,21,24] For three of the studies considering junior doctor intake we combined monthly infection rates to generate a total for the summer period,[6,12,21] for the remaining study junior doctor intake month (July) coincided with the middle of summer and was compared to the remainder of the year.[24] Of the 12 included manuscripts the study by Anthony *et al.* and McDonald *et al.* contributed the highest weighting.[8,24] Anthony *et al.* found that the risk of a surgical site infection was highest for patients discharged in the summer month of June and lowest in December (adjusted OR 1.24, 95% CI 1.16–1.31).[8] From the study by McDonald *et al.*

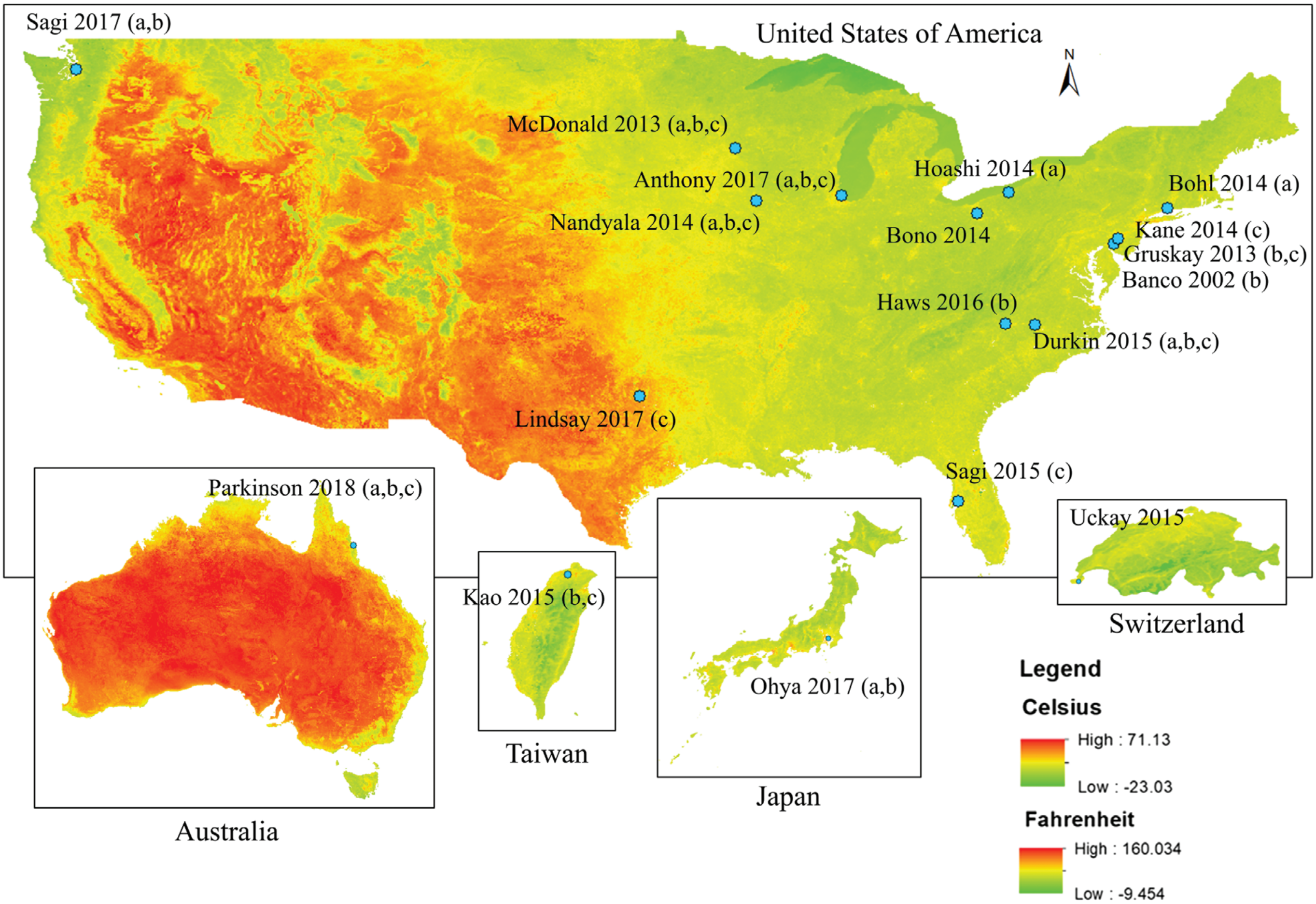


Fig. 2. Choropleth showing annual average temperature across regions and the location of first author institution for all studies included in systematic review. (a) Multi-site study or study using national database information; (b) included in meta-analysis; (c) did show increased infection during higher temperature period.

Table 1 Summary of key study characteristics and effect size calculations for all included studies

Study	Cases (*n*), study population (*n*)	'Higher temperature time of year' definition	Infection post-surgery	
			Higher temp time of year	Other times of year
Anthony, 2017[8]	4478 (760 283)	Summer (not defined)	—	—
Banco, 2002[6]	72 (1324)	Summer (June–August)	13/347	63/997
Bohl, 2014[19]	196 (21 434)	First academic quarter (not defined)	—	—
Bono, 2014[20]	1659 (—)	Summer (July–September)	—	—
Durkin, 2015[9]	642 (57 559)	Summer (June–September)	243/18 958	399/38 602
Gruskay, 2013[10]	276 (8122)	Summer (July–September)	84/2053	192/6069
Haws, 2016[7]	99 (14 521)	Warmer months (May–September)	49/6102	50/8419
Hoashi, 2014[21]	17 (575)	Summer (June–August)	7/207	10/368
Kane, 2014[11]	17 (750)	Summer (July–September)	9/191	8/567
Kao, 2015[22]	22 (61)	Hottest half of year (May–October)	18/40	4/21
Lindsay, 2017[23]	209 (–)	Summer (June–August)	73/—	136/—
McDonald, 2013[24]	9128 (968 086)	June and July	1460/147 004	7688/821 082
Nandyala, 2014[25]	— (52 499)	Summer (not defined)	—	—
Ohya, 2017[12]	438 (47 252)	Summer (June–August)	104/12 318	334/34 934
Parkinson, 2018[26]	844 (219 983)	Summer & Autumn (December–May)	38/3873	23/4471
Sagi, 2017[13]	390 (5127)	Summer (June–August)	117/1501	264/3625
Sagi, 2015[5]	58 (1128)	Spring & Summer (March–August)	31/565	21/553
Uckay, 2015[27]	455 (—)	Summer (not defined)	129/—	326/—

we calculated an increased risk of infection for patients who underwent spinal surgery during the summer month of July compared to the rest of the year (OR 1.06, 95% CI 1.00–1.13, $P < 0.0001$). A forest plot showing ORs for individual studies and a pooled OR with 95% CI is shown in Figure 3. Effect size calculations are shown in Table 1. There was a moderate level of heterogeneity

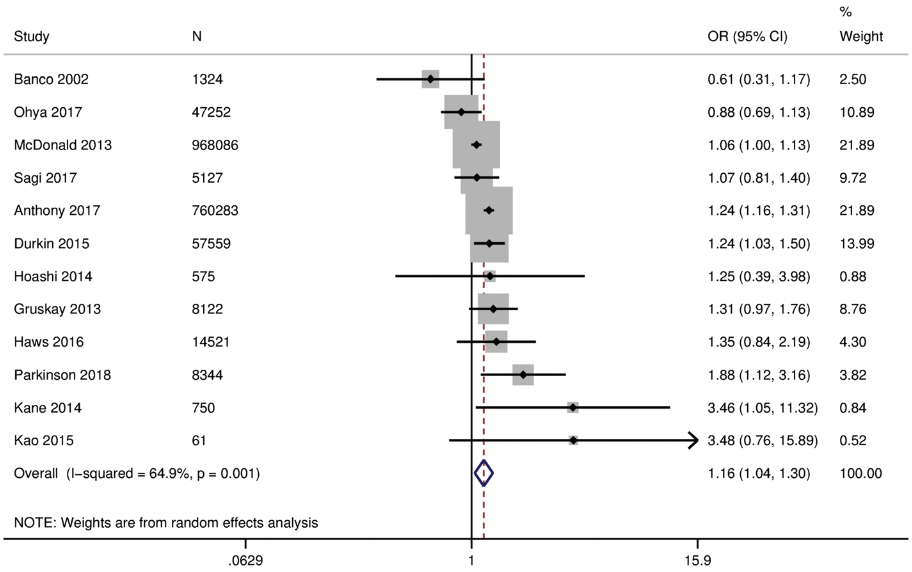


Fig. 3. Forest plot showing risk of infection in warmer time of year compared to other calendar periods.

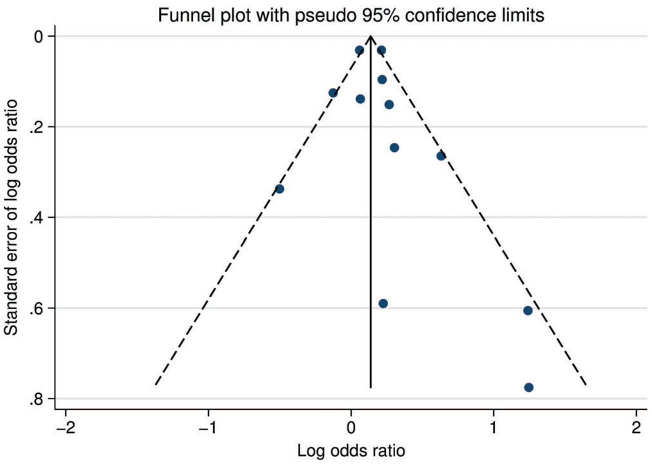


Fig. 4. Funnel plot.

across studies as indicated by an I^2 statistic of 64.9%. If heterogeneity was present it was explored further for the subgroups of how seasons were defined and whether adjustment factors were used. Climate subgroups (i.e. tropical and non-tropical) could not be explored due to the use of national databases spanning both tropical and non-tropical regions. Our random effects model gave appropriate weighting to individual studies based on the heterogeneity identified. A funnel plot showing no evidence of small study bias is shown in Figure 4 (bias coefficient 0.37, 95% CI 1.07–1.18, $P = 0.58$).

Risk of bias

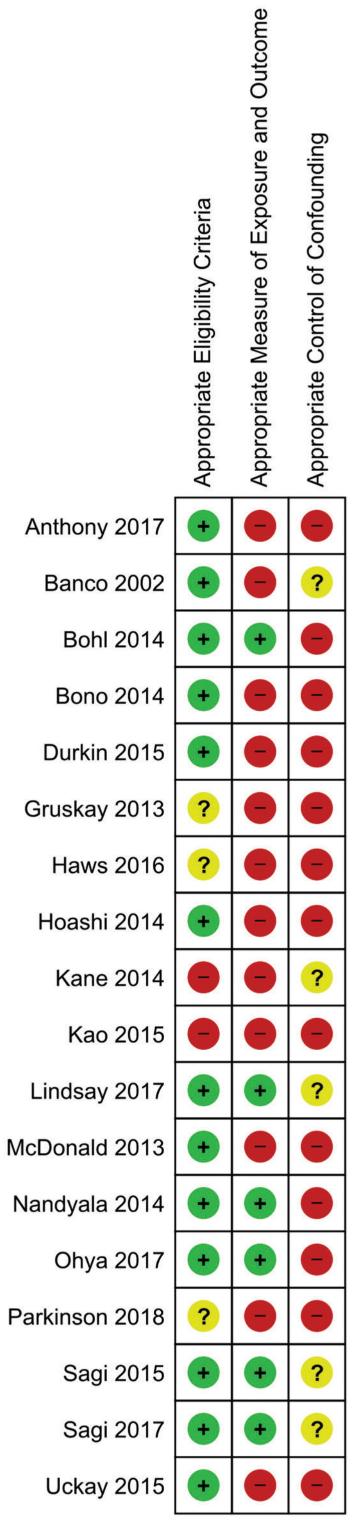
Observational studies are automatically assigned a low quality of evidence rating according to the Cochrane Risk-of-Bias tool and Grading of Recommendations Assessment, Development and Evaluation method.[16,17] Overall the quality of the evidence was very low to low. The highest risk of bias was identified in regards to controlling for confounding with 75% of studies considered high risk. A risk of bias summary and graph are shown in Figures 5 and 6, respectively.

Discussion

This systematic review of 18 studies and meta-analysis of 12 studies identified an increased odds of post-operative infection for patients undergoing orthopaedic procedures during warmer times of the year (pooled OR 1.16, 95% CI 1.04–1.30). Despite the heterogeneous orthopaedic populations studied, low quality of evidence and variability in study designs we believe this finding is clinically relevant because it may help to improve infection surveillance. To our knowledge this is the first systematic review and meta-analysis on this topic.

The most commonly proposed mechanism for infection surges during warmer months is that higher temperatures combined with higher humidity generate a warm well hydrated cutaneous environment were bacteria proliferate to levels that increase the risk of surgical site infection.[9–11] Recent meta-genomic studies support this notion by demonstrating that primary infecting organisms in orthopaedics, namely staphylococcal species, prefer moist anatomic regions over sebaceous or dry body areas.[28] In a systematic review of *Staphylococcus aureus* infections across specialties, Leekha *et al.* concluded that the phenomenon of seasonality was most evident in skin and soft tissue infection rates and also attributed summer spikes to higher temperature and humidity.[29] In a robust and recent time series analysis of *S. aureus* infections among US paediatric patients, Wang *et al.* similarly argued that increased infections in the summer time were due to high humidity and temperature.[30]

We believe that several features of human behaviour confound this finding and that in light of the complexity of the cutaneous microbiome increased bacterial proliferation alone does not sufficiently explain seasonality. Though difficult to quantify, both Gruskay *et al.* and Durkin *et al.* suggest that behaviour during the warmer periods increases risk of post-operative infection because patients are more likely to delay health care seeking and to



	Appropriate Eligibility Criteria	Appropriate Measure of Exposure and Outcome	Appropriate Control of Confounding
Anthony 2017	+	–	–
Banco 2002	+	–	?
Bohl 2014	+	+	–
Bono 2014	+	–	–
Durkin 2015	+	–	–
Gruskay 2013	?	–	–
Haws 2016	?	–	–
Hoashi 2014	+	–	–
Kane 2014	–	–	?
Kao 2015	–	–	–
Lindsay 2017	+	+	?
McDonald 2013	+	–	–
Nandyala 2014	+	+	–
Ohya 2017	+	+	–
Parkinson 2018	?	–	–
Sagi 2015	+	+	?
Sagi 2017	+	+	?
Uckay 2015	+	–	–

Fig. 5. Risk of bias summary.

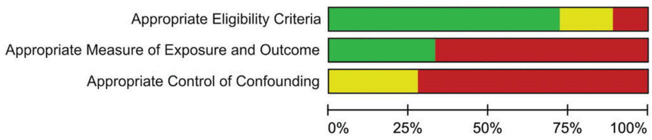


Fig. 6. Risk of bias graph. 🟩, Low risk of bias; 🟨, unclear risk of bias; 🟥, high risk of bias.

experience greater skin disruption from insect bites, sporting and trauma related injuries.[9,10,31] It is likely that demographically dependent factors including access to air-conditioning, patterns of antibiotic use and local recreational activity are also important. Patient over-crowding and hospital staff intake cycles should also be considered potential confounders with annual junior doctor intake explored as a risk factor for post-operative infection by six of the studies here.[6,12,19,21,24,25] Though junior doctor intake was not the focus of our meta-analysis we believe it may contribute to overall increased odds of infection particularly when coinciding with higher temperature months. Finally, an emerging understanding of the cutaneous microbiome has demonstrated that in addition to proliferation, the reduction of some low frequency but important regulatory bacteria also contributes to infection risk.[28]

There were several limitations shared across included studies. Primarily, all but one study used calendar dates as a proxy for temperature and did not analyse infection rates against specific temperature or humidity ranges. Consequently, we were unable to identify odds of infection based on specific conditions. This limitation was heightened by variable definitions of the warmer time of year. We also noted that the use of national databases by several studies made it difficult to identify if specific environments were more likely to experience peaks in response to warmer weather. For instance, though we believe that the seasonality effect may be greater in tropical regions this was difficult to determine, particularly from studies that reported national data capturing variable environments. Additionally, though time series analysis has been shown to be the most robust statistical measure of seasonality none of the studies used this method.[1] Finally, we found that very few authors reported causative organisms, despite Gram-negative and Gram-positive infections predominating at different times of the year.[1,28,29]

There are also limitations to our meta-analysis. Firstly, the cases included represent a heterogeneous collection of orthopaedic patients and it is possible that the influence of higher ambient temperature is variable between subgroups of spinal surgery, fracture and arthroplasty patients. We could not account for this effect due to the small number of existing studies. We also excluded non-English articles and we expect that this may have resulted in an under representation of potentially important research from warmer, wetter regions including South America and South East Asia.

Conclusion

The current literature suggests there may be a small but significantly increased odds of post-operative infection for patients undergoing orthopaedic procedures during warmer times of the year. Though several mechanisms have been proposed no research to date has demonstrated causation and more robust studies are required to quantify the confounding variables.

Conflicts of interest

None declared.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1. Full search strategy.
Appendix S2. Study characteristics.