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Review

A systematic review of surgical site infections following day surgery: a frequentist and a Bayesian meta-analysis of prevalence

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Background: Since 1990, several studies have focused on safety and patient satisfaction in connection with day surgery. However, to date, no meta-analysis has investigated the overall prevalence of surgical site infections (SSI).
Aim: To estimate the overall prevalence of SSI following day surgery, regardless of the type of surgery.
Method: A systematic review and a meta-analysis of the prevalence of SSI following day surgery, regardless of the type of surgery, was conducted, seeking all studies before June 2016. A pooled random effects model using the DerSimonian and Laird approach was used to estimate overall prevalence. A double arcsine transformation was used to stabilize the variance of proportions. After performing a sensitivity analysis to validate the robustness of the method, univariate and multi-variate meta-regressions were used to test the effect of date of publication, country of study, study population, type of specialty, contamination class, time of postoperative patient visit after day surgery, and duration of hospital care.
Findings: Ninety articles, both observational and randomized, were analysed. The estimated overall prevalence of SSI among patients who underwent day surgery was 1.36% (95% confidence interval 1.1–1.6), with a Bayesian probability between 1 and 2% of 96.5%. The date of publication was associated with the prevalence of SSI (coefficient −0.001,

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$P = 0.04$), and the specialty (digestive vs non-digestive surgery) tended to be associated with the prevalence of SSI (coefficient 0.03, $P = 0.064$).

Conclusion: The meta-analysis showed a low prevalence of SSI following day surgery, regardless of the surgical procedure.

Introduction

Since the establishment of day surgery in the USA, UK and Canada in the 1960s, its practice has developed considerably. The advantages of day surgery include increased patient and surgeon satisfaction, more convenient scheduling and lower costs [1–4]. There has been a marked increase in day surgery for many common low-risk interventions that do not require hospitalization or postoperative stay for more than 24 h [1].

Although day surgery has many advantages, it is extremely important to monitor patients for postsurgical complications, especially surgical site infections (SSI). Moreover, it is known that SSI can constitute a financial burden for health centres and for patients, and are usually associated with increased morbidity and even mortality [3,5–7]. Definitions of day surgery differ between countries, and in France, day surgery is defined as any hospitalization of less than 12 h without overnight stay. This study used the International Association for Ambulatory Surgery (IAAS) definition which is 'A patient having an operation, procedure excluding an office/surgery or outpatient operation/procedure, who is admitted and discharged on the same working day' [8].

Since 1990, several studies around the world have focused on day surgery in terms of safety and patient satisfaction for various surgical procedures. Each study presents the results of their own institution in terms of complications following surgery, length of time in hospital and cost. However, little is known about the global prevalence of SSI following these procedures [1,4,9].

Ahmad *et al.* published a meta-analysis assessing various postoperative outcomes in day surgery patients vs inpatients undergoing laparoscopic cholecystectomy. In the same way, Hopkins *et al.* published a literature review focusing on general complications of thyroid surgery. However, neither Ahmad *et al.* nor Hopkins *et al.* reported SSI rates following surgery [10,11].

To date, no meta-analysis has reported the overall prevalence of SSI, regardless of the surgical procedure. Several estimates are available from studies published in different countries with different sample sizes, ranging from small (few dozen) to large (several thousand). Conducting a meta-analysis allowed the present authors to consider possible heterogeneity and to provide more accurate results by pooling different types of studies and specialties, thus strengthening the analysis.

After performing a systematic review, the authors used previously published and available studies to estimate the overall prevalence of SSI following day surgery related to different surgical procedures in a meta-analysis of prevalence.

Methods

The MOOSE (Meta-analysis Of Observational Studies in Epidemiology) and PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) statements were used as guidance for the completion of this meta-analysis [12–14].

Search strategy

An extensive unrestricted computerized literature search was conducted using several sources, including MEDLINE, ScienceDirect, Cochrane database and EMBASE.

To identify all studies published before June 2016, the search terms 'day surgery', 'ambulatory surgery', 'same-day surgery', 'day-only surgery', 'surgical site infections' and 'wound complication' were used, as defined in IAAS terminology [8]. The term 'outpatient surgery' was also used, as this was in common use before the second edition of the IAAS definition (2014) [2].

Studies with potentially relevant titles and abstracts were read. When the studies seemed to meet the eligibility criteria, or when information was insufficient to exclude them, the full article was read by two reviewers (DP and LSAG) to determine those that provided sufficient information for inclusion in the meta-analysis. Any discrepancies between the two reviewers were resolved by consensus.

Finally, the references cited by each eligible study were scrutinized to identify additional articles.

Inclusion and exclusion criteria

Studies were restricted to those published in English, German, Italian, Dutch and French. The definitions of SSI were those used by the authors of each study. Studies were included if they reported extractable data on the prevalence of SSI following day surgery, regardless of the type of surgery.

The numerator for this study was the presence and number of SSI following day surgery, and the denominator was the number of subjects who underwent day surgery.

Studies that provided data on two or more periods were also included. There were no restrictions concerning study design.

Articles that did not deal with day surgery and the prevalence of SSI were excluded. If either the numerator or denominator values were unavailable, the article was excluded.

Studies focusing solely on patient satisfaction or presenting complications following day surgery in general were not included. Articles with duplicated data were also excluded.

For each included article, the following epidemiological data were recorded: study design (randomized controlled trial; cross-sectional, prospective and retrospective studies), country of study, date of publication, type of specialty (digestive surgery, thyroid surgery, other surgery specialties or multiple specialties), contamination class (clean and clean-contaminated, contaminated and dirty, combined), status of the population included (children, adults or combined), duration of hospital care for day surgery ($<$12 h, $<$23 h, not available) and time of follow-up. The type of surveillance, SSI definition and interventional character were not mentioned in articles.

In order to limit publication bias, the authors searched the Open Grey database, which is known to be one of the biggest grey literature databases to seek unpublished studies. Indeed, grey literature can include original articles that have not been published in addition to technical reports, dissertations, congress presentations or official publications. This search identified dissertations ($N = 14$), a poster and a conference; however, these did not meet the inclusion criteria and were thus not included in the analysis.

Statistical analysis

A systematic review focusing on SSI following day surgery was performed in order to estimate it in a meta-analysis.

First, to estimate the global prevalence of SSI following day surgery, a double arcsine transformation was used to stabilize the variance of proportions [15]. I^2 was used as a measure of heterogeneity. I^2 values > 50% were defined as high heterogeneity. A pooled random effects analysis was used to calculate the combined prevalence of SSI following day surgery and their 95% confidence intervals (CIs) using the DerSimonian and Laird approach [16]. The Restricted Maximum Likelihood Estimation (REML) method and the Sidik—Jonkman method were used to estimate Tau [17].

A cumulative meta-analysis that included studies from the oldest to the most recent was also performed. Sensitivity analyses were undertaken to assess the robustness of the statistical methodology by removing each study one by one.

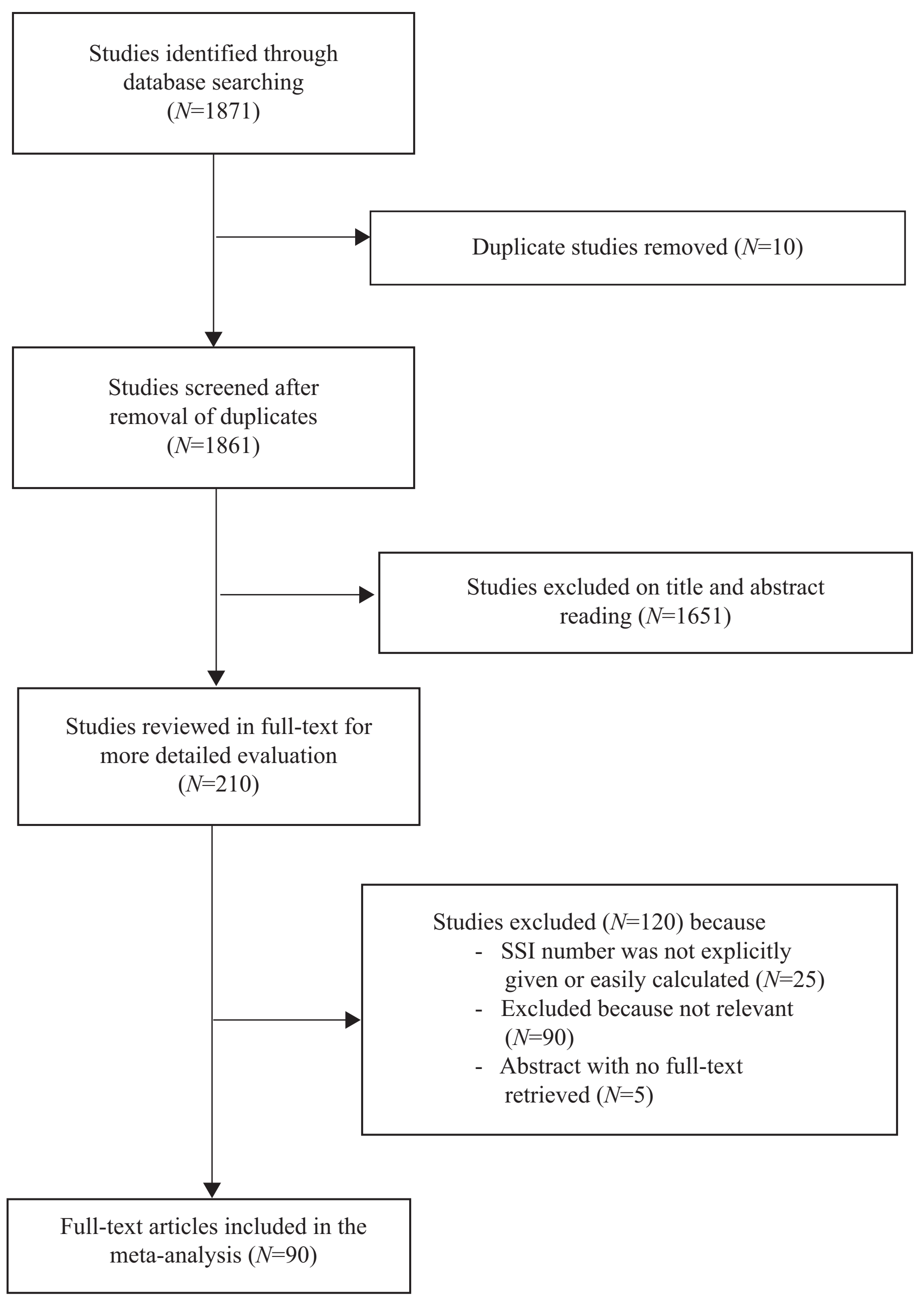

Figure 1. Flow chart showing the study selection process. SSI, surgical site infection.

Table I
Description of variables presented in subgroup analyses

Subgroups	Number of studies ($N = 94$)	Proportion (%)	Pooled prevalence (%) from subgroup analyses	95% CI	I^2 between subgroups (*P*-value)
Date of publication	94		1.36	1.10–1.60	0.00
1975	1	1.1	6.4	3.60–10.40	
1990	2	2.1	4.0	2.60–5.60	
1991	1	1.1	0.5	0.01–3.00	
1994	3	3.2	2.4	0.20–6.10	
1995	4	4.3	3.9	0.00–15.10	
1997	4	4.3	2.5	0.50–5.60	
1998	3	3.2	0.006	0.00–0.01	
1999	4	4.3	2.9	0.00–11.70	
2000	2	2.1	0.6	0.00–2.00	
2001	5	5.3	2.2	1.50–3.00	
2002	3	3.2	0.6	0.02–1.60	
2003	3	3.2	1.3	0.00–7.60	
2004	5	5.3	1.5	0.09–4.00	
2005	6	6.4	1.9	0.50–4.10	
2006	5	5.3	1.0	0.08–2.70	
2007	4	4.2	1.5	0.00–5.10	
2008	7	7.4	2.8	1.30–4.70	
2009	2	2.1	1.0	0.10–2.50	
2010	3	3.2	1.6	0.10–4.60	
2011	2	2.1	2.5	0.00–9.10	
2012	3	3.2	0.9	0.02–2.50	
2013	4	4.2	4.9	0.10–10.60	
2014	12	12.8	0.7	0.30–1.20	
2015	5	5.3	0.3	0.00–0.90	
2016	1	1.1	0.04	0.02–0.08	
Country of study					0.00
USA and Canada	33	35.11	0.6	0.4–0.80	
UK	17	18.09	4.3	2.2–6.80	
Europe	29	30.85	1.3	0.5–2.30	
Other countries	15	15.96	2.6	0.8–5.10	
Study design					0.04
RCT	5	5.32	2.8	1.1–5.18	
Observational studies	89	94.68	1.3	1.1–1.60	
Type of specialty					0.00
Digestive surgery	36	38.71	3.6	2.4–5.00	
Thyroid surgery	11	11.83	0.7	0.2–1.40	
Other surgical specialties	28	30.11	1.5	0.8–2.50	
Multiple specialties	18	19.35	0.9	0.5–1.30	
Specialty (grouped)					0.00
Digestive surgery	36	38.30	3.8	2.5–5.21	
Non-digestive surgery	58	61.70	0.87	0.6–1.15	
Class of contamination					0.00
Clean and clean-contaminated	69	74.19	1.0	0.8–1.30	
Contaminated and dirty	5	5.38	3.0	0.4–7.40	
Combined	19	20.43	2.0	0.9–3.40	
Status of the population					0.00
Children	82	87.23	2.6	1.3–4.30	
Adults	10	10.64	1.2	0.9–1.50	
Combined	2	2.13	7.3	4.5–10.60	
Duration of hospital care					
<12 h	8	8.5	[a]	[a]	
<23 h	25	26.6	[a]	[a]	
Not available	61	64.9	[a]	[a]	

CI, confidence interval; RCT, randomized controlled trial.
[a] Parameters could not be estimated because of the amount of missing data.

Table II
Time between day surgery and postoperative consultations in the study population sorted by year

Authors	Year	Population	Postoperative consultation 1 (days)	Number of subjects 1	Postoperative consultation 2[a] (weeks)	Number of subjects 2
Lewis *et al.* [67]	1975	233	7	233	NA	NA
Zoutman *et al.* [106]	1990	515	30	NA	NA	NA
Young *et al.* [105]	1994	99	10	10	6–8	NA
Weltz *et al.* [104]	1995	16	10	NA	NA	NA
Keulemans *et al.* [61]	1998	37	7	NA	6	NA
Manian *et al.* [21]	1998	3661	30	NA	NA	NA
Manian *et al.* [21]	1998	3580	30	NA	NA	NA
Mezei *et al.* [74]	1999	17,638	30	NA	NA	NA
Velhote *et al.* [102]	1999	124	2	NA	4 days	NA
Hollington *et al.* [54]	1999	60	7	NA	NA	NA
Lau *et al.* [66]	2000	265	1	NA	3 days	NA
Gabrielli *et al.* [47]	2001	1000	3	NA	1	NA
Vilar-Compte *et al.* [103]	2001	1350	30	NA	NA	NA
Grøgaard *et al.* [50]	2001	642	7	4	4	18
Sewonou *et al.* [91]	2002	5183	15	NA	3	NA
Minatti *et al.* [75]	2002	223	13	NA	4	NA
Chok *et al.* [37]	2004	64	1	NA	3 days	NA
Hashemi *et al.* [52]	2004	1003	5	4	2	7
Kurzer *et al.* [64]	2004	54	7	NA	2–6 years	NA
Mlangeni *et al.* [76]	2005	16,045	30	NA	NA	NA
Hirsemann *et al.* [53]	2005	1095	46	NA	NA	NA
Lieng *et al.* [68]	2005	41	1	NA	3–4	NA
Sahai *et al.* [88]	2005	104	1	NA	NA	NA
Brebbia *et al.* [34]	2006	226	7	NA	2	NA
Osuigwe *et al.* [9]	2006	140	5	NA	NA	NA
Spiegelman *et al.* [95]	2006	32	2–3	NA	2	NA
Engbaek *et al.* [43]	2006	13,907	60	NA	NA	NA
Bona *et al.* [32]	2007	206	1	NA	2 days	NA
Proske *et al.* [82]	2007	211	1	NA	1–2	NA
Dionigi *et al.* [39]	2008	112	5	2	1	1
Usang *et al.* [99]	2008	88	4	NA	2	NA
Obalum *et al.* [78]	2008	72	7	NA	2 years	NA
Bergenfelz *et al.* [31]	2008	3660	7–42	NA	24	NA
Trottier *et al.* [98]	2009	232	1	NA	2	NA
Jensen *et al.* [59]	2009	113	2	NA	NA	NA
Snyder *et al.* [94]	2010	1064	30	NA	NA	NA
Ilie *et al.* [56]	2011	14	30	NA	NA	NA
Mattila *et al.* [73]	2011	46	15	46	NA	NA
Alkhoury *et al.* [25]	2012	126	14	NA	NA	NA
van Boxel *et al.* [101]	2013	211	30	NA	NA	NA
Pugely *et al.* [83]	2013	1652	30	NA	NA	NA
Martin-Ferrero *et al.* [71]	2014	10,032	2	NA	1	NA
Owens *et al.* [22]	2014	284,098	14	877	NA	NA
Owens *et al.* [22]	2014	284,098	30	1376	NA	NA
Jiang *et al.* [60]	2014	14,484	1	NA	3 days	NA
Putnam *et al.* [23]	2014	42	14	NA	4	NA
Putnam *et al.* [23]	2014	75	14	NA	4	NA
Putnam *et al.* [23]	2014	195	14	NA	4	NA
Lim *et al.* [69]	2014	6624	30	NA	NA	NA

NA, not available.
[a] Time between postoperative consultation and day surgery is given in weeks; otherwise, the unit is detailed.

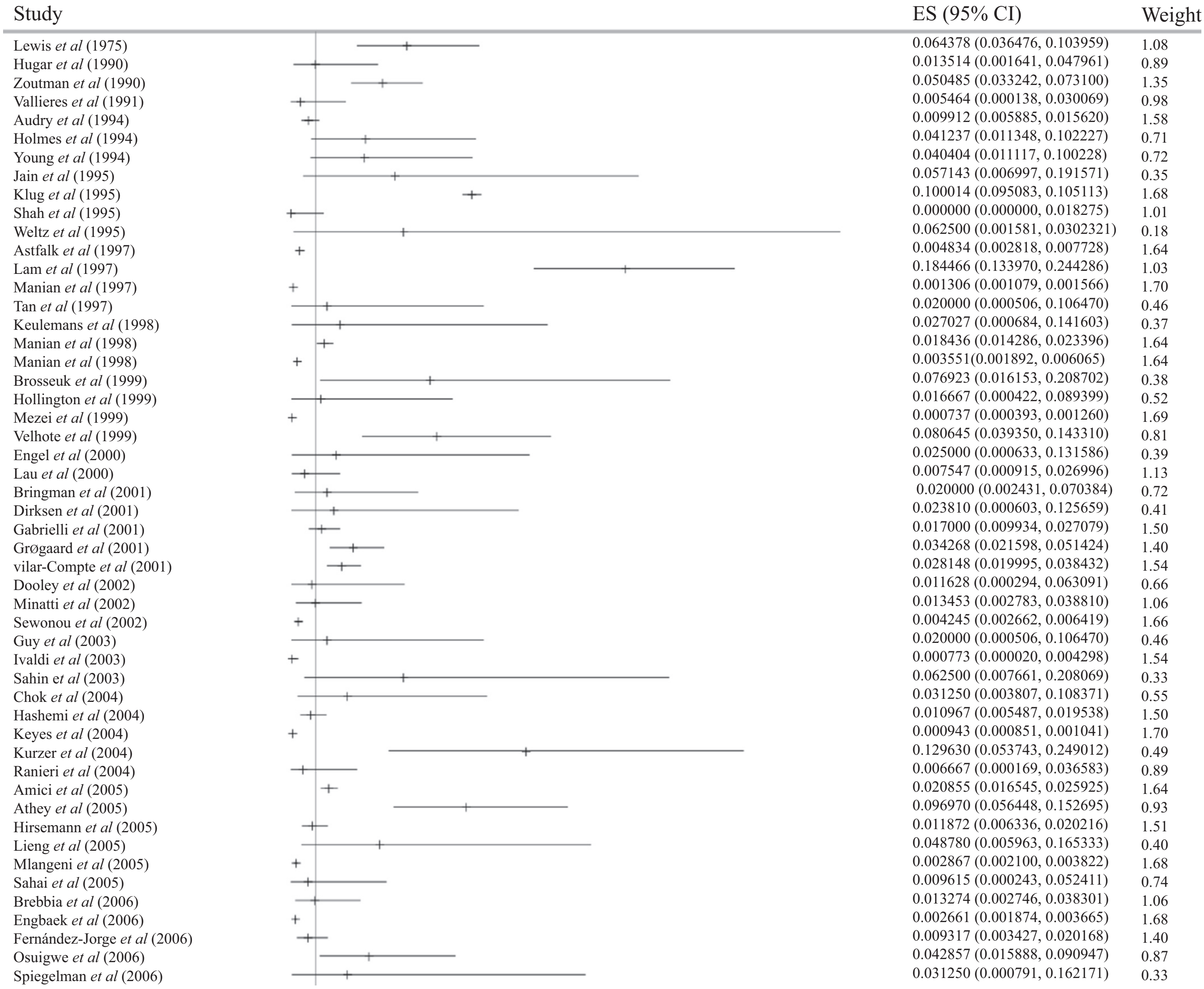

Figure 2. Forest plot.

Publication bias was explored by Egger's test, and represented graphically with a funnel plot to seek asymmetry [18].

Second, univariate meta-regressions were performed to test the effect of date of publication, population included, country of study, existence of a randomized clinical trial or not, type of specialty presented in each study, class of contamination, time of the post-operative patient visit after day surgery and duration of hospital care on the prevalence of SSI. The authors decided not to use multiple imputations or to remove studies with missing data in the meta-regression when the amount of missing data was high (>50%).

Subgroup analyses were performed with each of the variables presented above.

Third, to better understand the factors associated with SSI following day surgery, a multi-variate analysis using a backward selection algorithm was performed. Only variables reported in totality in studies were eligible for the multi-variate model.

All variables with $P < 0.25$ in the backward selection algorithm were evaluated. Variables with $P < 0.05$ in the final multi-variate model were considered significant. The overall statistical analysis was validated internally using a Bayesian model with a binomial distribution. This model is more accurate than the frequentist model as it can incorporate zero-events studies without either correction or transformation. Non-informative priors were used for the Bayesian model. From these priors and each explicative variable, the model was estimated by Monte Carlo Markov Chain sampling techniques. The precision of these estimates is given with 95% credible intervals (95% CrIs). Estimating the probability that the prevalence obtained lies in the CrI provided was then calculated using the interval hypothesis test.

STATA 14 ('metaprop' package; bayesmh command) and R 3.1.1 ('meta' and 'metafor' packages) were used for the analyses [19,20].

Results

In total, 1871 articles were obtained by the search strategy. Among these, 90 met the eligibility criteria (Figure 1). Three studies [21–23] provided data on two or three periods. They

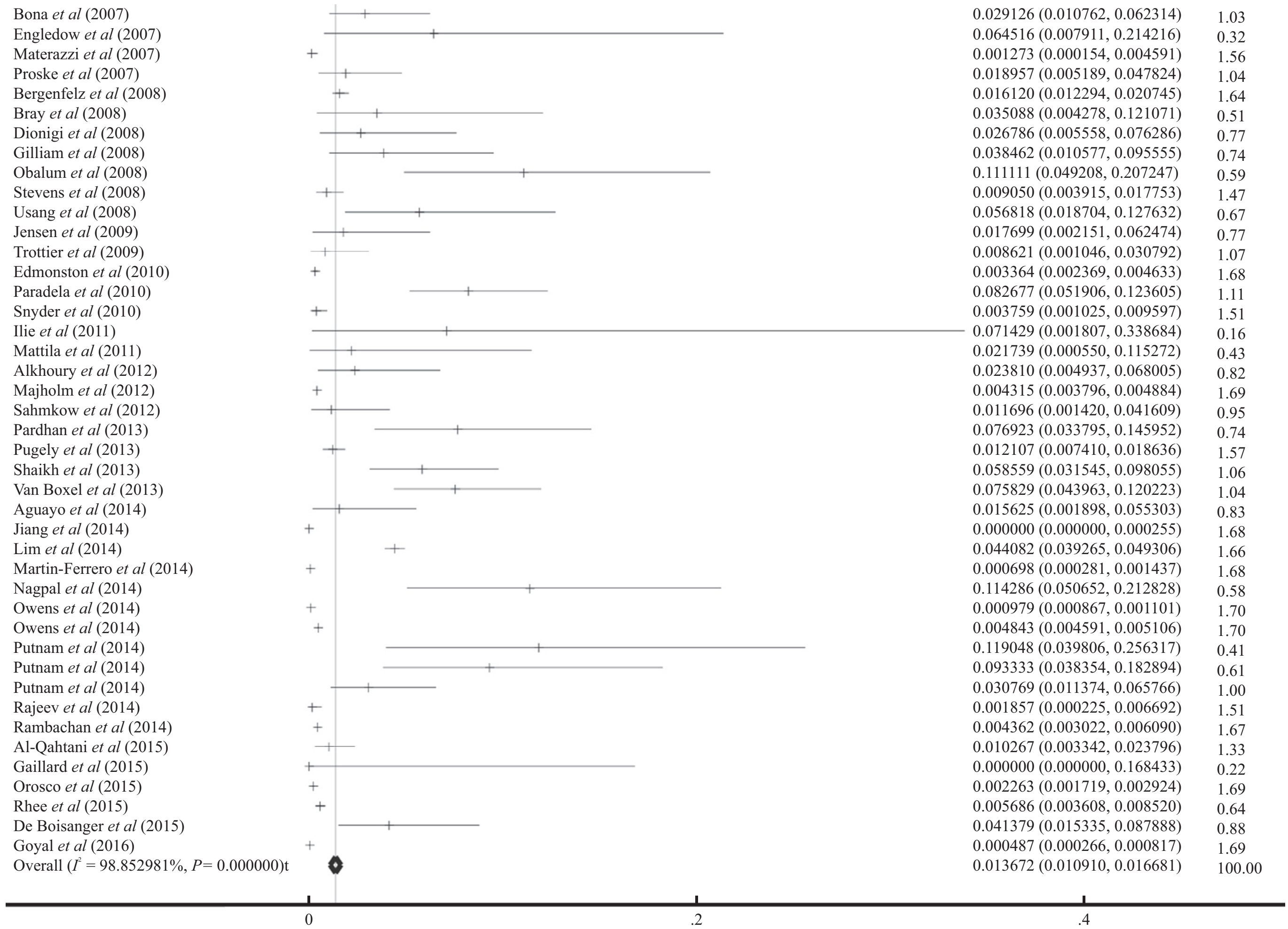

Figure 2. (*continued*).

were included as two or three distinct articles. Thus, 90 articles led to 94 sets of data for analysis [4,9,21–108].

Description of included studies

Most studies (60%) were conducted in the USA ($N = 33$) and Europe ($N = 29$) (Table I).

The size of the sample varied from 14 patients [56] to 411,670 patients [62], with a median of 211 patients (interquartile range 97.5–1775). Overall, 1,342,167 subjects were included.

Most studies included adult populations ($N = 82$). Ten studies only involved children, and two studies included populations of all ages. Altemeier classes I and II were the most frequent, representing 74.2% ($N = 69$) of studies [109,110].

There were seven surgical specialties initially (urologic surgery $N = 3$; neurosurgery $N = 3$; orthopaedic surgery $N = 4$; thyroid surgery $N = 11$; digestive surgery $N = 36$; other surgical specialties $N = 18$; multiple specialties $N = 18$).

Some specialties which were poorly represented were regrouped in the variable 'type of specialty' that included four modalities (digestive surgery, thyroid surgery, other surgical specialties and multiple specialties). The variable 'type of specialty' was also recoded into a variable presenting digestive surgery vs non-digestive surgery called 'specialty' in order to increase power.

Duration of hospital care for day surgery was provided for <50 % of the studies.

The characteristics of each study are shown in Appendix A (see online supplementary material).

Most studies were observational but five studies were randomized clinical trials [9,40,54,61,73].

The time between day surgery and postoperative consultations was mentioned in 51 studies (Table II).

Prevalence of SSI

Using the REML method to estimate Tau, the estimated global prevalence of SSI following day surgery was 1.36% (95% CI 1.1–1.6). The heterogeneity was very high ($I^2 = 98.85\%$) (Figure 2).

Using the Sidik–Jonkman method to estimate Tau, the estimated prevalence of SSI following day surgery was 1.8% (95% CI 1.3–2.4). The heterogeneity was very high ($I^2 = 98.9\%$, 95% CI 98.8–98.9%).

As the heterogeneity was very high, subgroup analyses were performed to seek interactions between each explicative variable.

Using the Bayesian model, the estimated prevalence of SSI was similar (1.32, 95% CrI 0.9–1.8), with a probability that the prevalence of SSI lies between 1 and 2% of 96.5% (Appendix B, see online supplementary material).

The funnel plot shows asymmetry (Figure 3) which was confirmed by a significant Egger test ($P = 0.001$).

Sensitivity analyses led to consistent results. The pooled prevalence when each article was removed one by one remained nearly identical to the main prevalence using the REML method to estimate Tau (1.01%, 95% CI 0.55–1.5). The result was similar using the Sidik–Jonkman method (1.35%, 95% CI 1.1–1.6).

The influence of large studies (>10,000 individuals) was small, as shown when these studies were removed [4,22,42,43,60,62,63,70,71,74,76,79,107].

When the three largest studies [22,62], representing 73% of the overall population, were removed, the global prevalence was 1.8% (95% CI 1.36–2.3). There was no significant difference between the two prevalence rates.

Using the Sidik–Jonkman method to estimate Tau, the cumulative meta-analysis, which included studies from the oldest to the most recent, showed a slight trend towards a lower prevalence of SSI following day surgery in more recent studies, with a prevalence of 6.4% in 1975 (95% CI 3.6–10) compared with 1.8% in 2016 (95% CI 1.3–2.4). This also corresponded to the pooled prevalence obtained (Appendix C, see online supplementary material).

Subgroup meta-analyses

All analyses by subgroup (date of publication, country of study, study design, type of specialty or specialty, contamination class and population included) found intergroup heterogeneity (Table I).

Factors associated with the prevalence of SSI

Univariate meta-regressions showed a significant association between the prevalence of SSI and the date of publication (coefficient −0.001, $P = 0.037$). The prevalence of SSI decreases when the publication date is more recent. The type of specialty (four modalities) was not associated with the prevalence of SSI ($P = 0.29$) (see Table III for more details), with most SSI occurring after digestive surgery compared with thyroid surgery, other surgical specialties and multiple specialties. However, specialty (digestive vs non-digestive surgery) tended to be associated with the prevalence of SSI (coefficient 0.03, $P = 0.059$). No other potentially explicative variable was statistically associated with the global prevalence of SSI. For example, duration of hospital care (defined as a threshold <12 h or ≥12 h) for day surgery was not associated with the prevalence of SSI.

The time between day surgery and postoperative consultations, which was known in 52% of all studies, was not associated with the prevalence of SSI on univariate meta-regression (coefficient 0.0017, $P = 0.39$) (Table III).

Due to the large amount of missing data for the time to postoperative consultations in this meta-analysis, the authors compared ‘characteristics’ of studies with or without reported time to postoperative consultations. The relationship between the probability of having no time to postoperative consultations in studies (i.e. missing data) and the principal dependent variables was evaluated.

No dependent variables and no study population sizes were associated with the probability of having missing time to postoperative consultations ($P > 0.05$).

Eligible variables for multi-variate meta-regressions were ‘date of publication’, ‘study design’, ‘specialty’, ‘country of

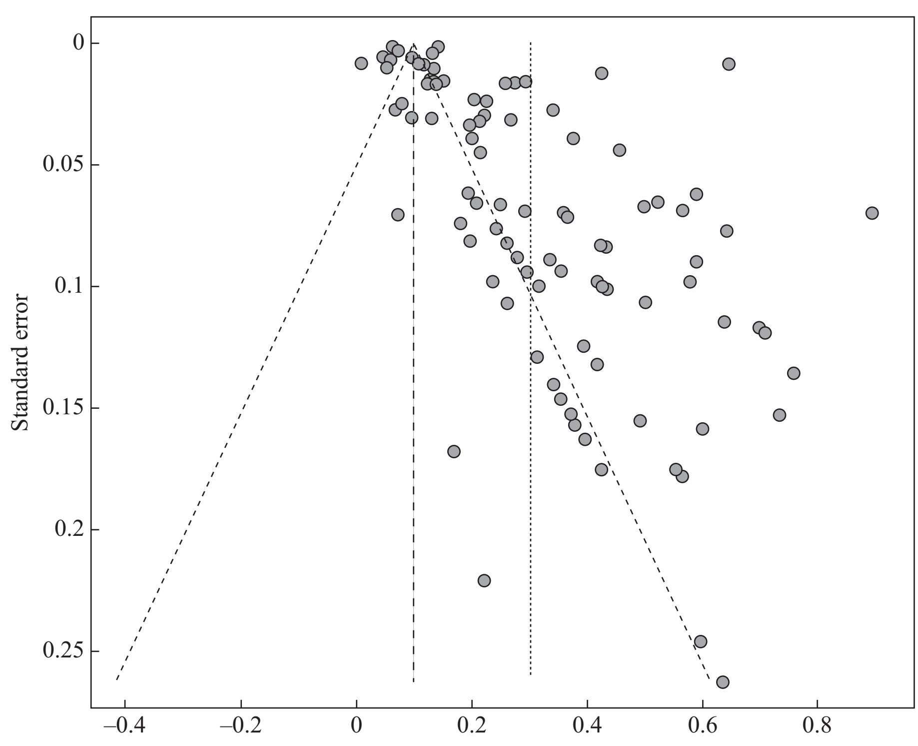

Figure 3. Funnel plot of the meta-analysis of the prevalence of surgical site infections following day surgery.

Table III
Univariate and multi-variate meta-regressions of the prevalence of surgical site infections following day surgery using the Restricted Maximum Likelihood Estimation method to calculate Tau ($N = 94$)

Variable	Univariate analysis		I^2 (%)	Multi-variate analysis	
	Coefficient (95% CI)	*P*-value[a]		Coefficient (95% CI)	*P*-value[b]
Date of publication[a,b]	−0.001 (−0.0021 to −0.0006)	0.037	45.41	−0.001 (−0.002 to −0.00004)	0.04
Time of first follow-up	0.0017 (−0.0022 to 0.00556)	0.39			
Duration of hospital care					
<12 h	ref				
<23 h	0.0087 (−0.0336 to 0.05089)	0.685			
Not available	0.0045 (−0.0341 to 0.04317)	0.816			
Global test		0.89			
Country of study			40.42		
USA and Canada	−0.006 (−0.035 to 0.023)	0.67			
UK	0.018 (−0.026 to 0.063)	0.40			
Europe	0.002 (−0.027 to 0.032)	0.86			
Other countries	ref				
Global test		0.46			0.86
Study design			46.67		0.92
Randomized controlled trials	0.017 (−0.094 to 0.128)	0.75			
Observational studies	ref				
Type of specialty			45.98		
Digestive surgery	ref				
Thyroid surgery	−0.034 (−0.073 to 0.004)	0.074			
Other surgical specialties	−0.027 (−0.061 to 0.007)	0.12			
Multiple specialties	−0.030 (−0.062 to 0.002)	0.07			
Global test		0.29			0.27
Specialty (grouped)[a]					
Digestive surgery[a]	0.030 (−0.001 to 0.062)	0.059		0.029 (−0.001 to 0.061)	0.064
Non-digestive surgery	ref			ref	
Contamination class			45.03		
Clean and clean-contaminated	ref				
Contaminated and dirty	0.014 (−0.046 to 0.074)	0.64			
Combined	0.007 (−0.009 to 0.023)	0.41			
Global test		0.65			0.96
Status of population included			46.74		
Children	−0.003 (−0.029 to 0.023)	0.79			
Adults	ref				
Combined	0.06 (−0.054 to 0.179)	0.29			
Global test		0.55			0.33

[a] Significant *P*-value <0.25.
[b] Significant *P*-value <0.05.

study', 'contamination class' and 'status of the population included'.

Performing the backward selection algorithm, the variables 'study design', 'country of study', 'contamination class' and 'status of the population included' were removed.

The final multi-variate meta-regression performed on 'date of publication' and 'specialty' showed an effect of time with a significant association with the prevalence of SSI (coefficient − 0.001, $P = 0.04$). Specialty also tended to be associated (coefficient 0.029, $P = 0.064$, see Table III for more details).

An effect of time was observed, with a significantly higher prevalence of SSI in studies conducted before 1990–91 [55,67,100,106] than after 1990–91 (highest prevalence in 1975, 6.4% (95% CI 3.9–10.4) [67], and the lowest prevalence in 2016 (0.04%, 95% CI 0.03–0.08) [107].

Discussion

In this meta-analysis of 90 studies, which included a majority of observational studies, the estimated overall prevalence of SSI following day surgery was quite low at 1.36% (95% CI 1.1–1.6), with a Bayesian probability of having a prevalence between 1 and 2% of 96.5%. Heterogeneity was very high (>50 %) and could be explained by each variable included in the analysis. The heterogeneity could also be due to other, non-tested variables. Sensitivity analysis did not show any differences in prevalence for studies that were duplicated or for studies with very large populations.

The date of publication was still associated with the prevalence of SSI on multi-variate analysis (coefficient −0.001, $P = 0.040$, 95% CI −0.0019 to −0.000045). The report of the European Centre for Disease Prevention and Control (ECDC) showed a decrease in SSI regardless of the type of surgery and country [111]. However, this decrease was only shown over two (2010–2011) or four years (2008–2011).

Several authors, including Rioux *et al.* [112], have noted a significant decrease in SSI rates over time. However, the time trend of Rioux *et al.*'s study was six years, compared with approximately 25 years (not including the 1975 study) in the present study. Also, Rioux *et al.*'s study was based on national surveillance data, while the present meta-analysis considered international data.

Since the study by Haley *et al.* [113], it has been well known that infection surveillance, regardless of anatomical site, contributes to a reduction in healthcare-associated infections over time. The present meta-analysis found a significant downward trend.

It could be thought that studies with a large population (>10,000 subjects) might influence the results for the overall prevalence of SSI [4,21,22,42,43,60,62,63,70,71,74,76,79,107]. However, as shown in the sensitivity analyses, as removing each study one by one did not change the overall prevalence, it is likely that the large studies did not influence the results. The largest study, published by Keyes *et al.* in 2004, was based on an analysis of internet databases from the American Association for the Accreditation of Ambulatory Surgery Facilities. More than 400,000 patients undergoing day surgery were included in this study, in which general and infectious complications were screened. Less than 1% of SSI were diagnosed in this cohort of plastic and reconstructive surgery [62].

Removal of the largest studies [979,866/1,342,167 patients (i.e. 70%)] led to no significant difference in prevalence (overlapping CI). Moreover, on the 94 sets of data analysed, only two were correlated; indeed, Owens reported the same outcome at two different times (14 days and 30 days post intervention) [22]. However, there was no impact on the global prevalence, as shown in the sensitivity analysis.

An effect of specialty (digestive vs non-digestive surgery) tended to be observed on univariate meta-regression ($P = 0.059$) and on multi-variate meta-regression ($P = 0.064$).

No other explicative variable influenced the overall prevalence. Surprisingly, whereas specialty tended to be associated with the prevalence of SSI, contamination class was not ($P = 0.96$).

In this meta-analysis, the global prevalence of SSI in patients undergoing digestive day surgery was 3.6% (95% CI 2.4–5.0). It is difficult to compare the prevalence of SSI in day surgery with that in conventional surgery since data provided by ECDC surveillance are stratified by specific type of surgery. For example, the incidence of SSI after cholecystectomy in conventional surgery was 1.4% (estimated 95% CI 1.3–1.5) in 2010–2011 [111]. Moreover, the comparison between the two prevalence rates might be limited by a potential under-estimation in conventional surgery. Indeed, one can suppose that national prevalence/incidence rates could be underestimated since data are provided by voluntary services. Rücker *et al.* provided evidence that the German KISS intensive care unit (ICU) surveillance network tended to underestimate the true incidence rates of nosocomial infections in German ICUs [114]. It could be the same with SSI.

Few data are available in the literature concerning the comparison of prevalence of SSI between day surgery and conventional surgery. This study found a global prevalence of SSI of 2.1% (95% CI 0.2–5.0) following day surgery vs 0.1% (95% CI 0.0–1.7] following conventional surgery. There was no significant difference (overlapping CI). This was confirmed using the Bayesian method: 1.46% (95% CrI 0.6–5.6) following day surgery vs 2.8% (95% CrI 0.0–24.1) following conventional surgery.

Day surgery is known to result in fewer postoperative complications, especially SSI, but this has to be confirmed further.

Patients undergoing day surgery are usually healthier (American Society of Anesthesiologists (ASA) score I or II) than inpatients as they are able to go to the hospital and have fewer common SSI risk factors (age, emergency surgery, contamination class, operative time) [4,32,91,107]. This has also been reported by Bona *et al.*, Majholm *et al.* and Goyal *et al.* This could lead to selection bias towards lower complications, including SSI. As stated by IAAS, 'The patient and their carer should be able to understand the planned procedure and subsequent postoperative care. The patient should be either fully fit or chronic diseases such as asthma, diabetes, hypertension or epilepsy should be well controlled. Patients should be selected according to their physiological status as found at assessment' [8].

This study used the prevalence of SSI because patient follow-up is rarely available (approximately 50%, $N = 51/94$). However, patient follow-up is necessary to calculate an incidence rate. As a reminder, incidence is defined as 'number of disease onset/sum of persons-time spent in population' [115].

Information on standardized and reproducible monitoring criteria was not often available. This can lead to a type of measurement bias in definition of the disease (SSI). It was hypothesized that this bias was non-differential. An example of a differential bias would be the existence of a relationship between the year of publication of articles and the use of standardized monitoring criteria. This study showed that there was no significant variation in prevalence rates according to the year of publication via meta-regression.

If information on standardized or non-standardized surveillance modalities had been available, a subgroup meta-analysis or meta-regression would have allowed this variable ('use of a standardized definition of surveillance') to be taken into account in adjusting the estimate of the prevalence rate of SSI.

The definitions of SSI and method of postdischarge surveillance must be taken into account as they can differ between studies and thus lead to bias in estimating overall prevalence [116,117]. Several methods for detecting SSI have been proposed, some of which take into account the existence of antibiotic therapy. This is the case for the studies by Yoko *et al.* [118,119]. Such data were not available in the studies analysed in this meta-analysis.

This study has some limitations. Firstly, a high degree of heterogeneity was observed, and variables included in the meta-regression could not explain this heterogeneity. Moreover, major risk factors of SSI such as ASA score, 75th percentile of operative time or median age were not provided in all of the studies. However, these variables could probably explain, in part, the heterogeneity found.

Several potential sources of heterogeneity have not been studied because they were lacking, including revision surgery, antibiotic prophylaxis and ASA score.

It is likely that at-risk and dirty surgeries are performed less often as day surgery. This could lead to a smaller number of such interventions, thus contributing to the asymmetry observed. Moreover, this asymmetry is probably due to the very high heterogeneity.

Thirdly, the majority of the studies included were observational studies. There were only five randomized clinical trials, thus inducing a potential methodological bias [9,40,54,61,73].

This study is the first meta-analysis to assess the prevalence of SSI following day surgery, which may be useful for the practice of surgeons and for national campaigns promoting day surgery. This is the first meta-regression to investigate the influence of all the main SSI factors, and the first meta-analysis to use a frequentist and a Bayesian approach on this topic.

The main result of this study is that the overall prevalence of SSI was low (1.36%), and probably lower than the prevalence of SSI in conventional surgery. This result was confirmed using a Bayesian model with uninformative priors that support the robustness of the methodology.

This analysis showed huge heterogeneity. As such, it is important to complete a precise methodological framework for surveillance. It is necessary to have good quality studies in the field of day surgery in order to estimate infectious or non-infectious complications precisely, taking into account potential confounding factors.

Further studies are needed to better understand the predictive factors associated with the prevalence of SSI following day surgery in comparison with inpatients following the same type of surgical procedure in order to develop specific infection control strategies.

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Appendix A. Supplementary data

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