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State of the Science Review

Incidence of sharps injuries in surgical units, a meta-analysis and meta-regression

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Glove perforations
Surgery
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ABSTRACT

Background: Sharps injuries occur often among surgical staff, but they vary considerably.
Methods: We searched PubMed and Embase for studies assessing the incidence of sharps injuries. We combined the incidence rates of similar studies in a random effects meta-analysis and explored heterogeneity with meta-regression.
Results: We located 45 studies of which 11 were randomized control trials, 15 were follow-up studies, and 19 were cross-sectional studies. We categorized injuries as self-reported, glove perforations, or administrative injuries. We calculated the population at risk as person-years and as person-operations (po). Meta-analysis of the incidence rate based on the best outcome measure resulted in 13.2 injuries per 100 time-units (95% confidence interval [CI], 4.7-37.1; $I^2 = 100\%$). Per 100 person-years, the injury rate was 88.2 (95% CI, 61.3-126.9; 21 studies) for self-reported injuries, 40.0 for perforations (95% CI, 19.2-83.5; 15 studies), and 5.8 for administrative injuries (95% CI, 2.7-12.2; 5 studies). Per 100 po, the respective figures were 2.1 (95% CI, 0.8-5.0; 4 studies), 11.1 (95% CI, 6.6-18.9, 15 studies), and 0.1 (95% CI, 0.05-0.21). I^2 values were all above 90%. Meta-regression indicated lower incidence rates in studies that used perforations per po.
Conclusions: A surgeon will have a sharps injury in about 1 in 10 operations . Reporting of sharps injuries in surgical staff should be standardized per 100 po and be assessed in prospective follow-up studies.

BACKGROUND

Sometimes healthcare workers (HCWs) injure themselves with a sharp object that has been contaminated with blood or body fluids from a patient by sticking it or cutting it through their own skin. When the patient is infected with a bloodborne virus like HIV, hepatitis B virus, or hepatitis C virus, these diseases can be transmitted to the HCW. These injuries are also referred to as percutaneous exposure injuries, needlestick injuries, or sharps injuries. In this review, we use the term *sharps injuries*. The risks of infection are small, but the consequences are potentially serious. An effective vaccine is available for hepatitis B virus but not for other bloodborne diseases. Therefore, it is important to prevent injuries that can put the HCW at risk for bloodborne diseases.

It is unsurprising that approximately 30% of all reported sharps injuries happen in the surgical department.[1] Most of these injuries happen during operations with suture needles or other sharp instruments. Preventive interventions, such as blunt surgical needles and double gloving, have been developed and shown to effectively reduce the number of sharps injuries.[2,3] However, their implementation could be much improved according to recent surveys of surgeons.[4]

To be able to assess the burden of disease, the consequences of sharps injuries, or the absolute effects of preventive interventions, it is necessary to know how frequently these injuries occur. For example, the World Health Organization (WHO) made an estimation of the burden of disease resulting from sharps injuries.[5-7] Consequences of these injuries, such as blood tests and postexposure prophylactic treatment, are expensive. One of the most important parameters to know to be able to assess the costs involved with sharps injuries is the incidence of these injuries.[8,9]

Assessing the occurrence of sharps injuries is not easy, because there is no single valid way of assessment. Basically, sharps injuries can be assessed by observation or by self-report.

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A sharps injury can be observed by inspecting the surgeon's hands for blood after an operation and after the gloves have been taken off. However, it is unclear if this observation will include all spots where contamination can occur. Sharps injuries can also be observed indirectly when a HCW wears gloves and the gloves become perforated because of a sharps injury. Glove punctures can be measured in a valid way by filling the gloves with air and then placing them under water.[10] However, it would still be necessary to assess how often the puncturing of gloves leads to a sharps injury.

Self-reports can be obtained in several different ways. To be able to implement a postexposure policy and to assess the effects of preventive policy, hospitals require sharps injuries to be officially reported (eg, to the occupational safety and health department). This requires considerable motivation of the reporter, and when asked, HCWs state that they do not report all injuries sustained.[11] A study found that when the reporting was made easier, the number of sharps injuries reports doubled.[12] Another way of collecting self-reports is by dedicated surveys, diaries, or interviews. Surveys are mostly used when HCWs are asked how many sharps injuries they have sustained during their career or during a certain time period. These methods suffer from recall bias that will either increase or decrease the likelihood of sharps injuries depending on how much the event has affected the HCW.

It is obvious that the incidence of sharps injuries based on surveys varies widely. For example, 1 study in 2008 in the United Kingdom found 100 sharps injuries per 100 person-years (py) among surgeons, whereas another study found 1,000 sharps injuries per 100 py also among surgeons in the United Kingdom in 2010.[11,13] The lack of a standardized way of asking and reporting also explains some of the difference in findings.

Combining the results of these different types of studies and observations into reliable estimates of sharps injuries and reports of these injuries is not easy. The WHO Global Burden of Disease project used a number of 64 sharps injuries per 100 py for HCWs in Europe based on a survey of the literature up to 2003 but did not provide any details about the methods used to come to these figures.[7] Another review conducted in 2006 reports an incidence of sharps injuries ranging from 1-5 per 100 py obtained with standard hospital reporting systems and a range from 30-284 per 100 py obtained with retrospective questionnaires.[14] Differences in methods and disciplines of reporting may also explain some of these variations.

Many more reports of sharps injury surveys have been published following the reviews mentioned earlier. Therefore, we conducted a systematic review of studies reporting the incidence of sharps injuries in surgical staff to be able to estimate the incidence of sharps injuries in surgical staff.

METHODS

We conducted the review according to an a priori developed protocol that was registered in the Prospero database with registration number CRD42018086861.

Criteria for considering studies for this review

Types of studies

We included prospective and retrospective follow-up studies that measured both the number of new sharps injuries and the population at risk for these sharps injuries. We defined prospective studies as studies that collected the data from participants after the study was planned. We defined retrospective studies as studies that used administrative data already collected before the study was planned or asked the participants to recall how many sharps injuries they had in a specific period. To diminish the role of recall bias in retrospective studies, we excluded studies that asked participants to report sharps injuries over a period that lasted longer than 1 year. We also included randomized control trials (RCTs) of interventions to prevent sharps injuries. From these RCTs, we included the control group only to prevent a too large influence of preventive interventions.

We included studies only if they contained sufficient information to calculate the incidence of sharps injury over a certain amount of person-time or an equivalent measure such as the number of operations. This meant that information on the number of sharps injuries and the amount of person-time over which the events were observed had to be available in studies.[15] We excluded studies that related the risk to hospital beds, as we considered this not a reliable indicator of the amount of person-time.

Because of the HIV epidemic, many sharps injury studies were carried out in the 1990s. However, since then many preventive measures have been taken, such as mandatory use of engineered devices and instruments and double gloving. Therefore, we believed that the older studies would not give a valid indication of the risk of sharps injuries anymore, and we restricted the inclusion of studies to those that were published after the year 2000.

Types of participants

We included studies conducted with all types of surgeons and other surgical staff, such as scrub nurses, residents, or students. We also included studies with obstetricians and midwives, as they would be similarly exposed to contaminated body fluids through sharps injuries.

Types of outcome measures

Considering that we had no preconceived idea about which would be the best measure of the incidence of sharps injuries, we included studies with any measurement of sharps injuries, such as self-report in questionnaires, interviews, diaries, administrative systems, or observations of injuries, or proxy measures, such as perforations in gloves.

Search methods for identification of studies

We developed the search strategy based on the concepts of sharps injuries and surgeons. We developed search words for both concepts and combined these with the Boolean operator 'AND.' We searched both the MEDLINE database and the Embase database for relevant studies from inception to January 2, 2018. The full searches are reported in Supplementary Appendix S1. We checked the Cochrane Database of Systematic Reviews to evaluate the effectiveness of various interventions to prevent sharps injuries for studies that were potentially missed by our systematic search.

Selection of studies

The references that resulted from the search were uploaded into the program Covidence (www.covidence.org; Covidence, Melbourne, Australia). The 2 review authors (JV and PB) selected the references based on the title and abstract into "clearly irrelevant" or "possibly included." We retrieved full texts for the possibly included references, uploaded these into the Covidence program, and assessed if these studies fulfilled the inclusion criteria.

Data extraction and management

We extracted the following data from the included studies: year of study, study design, type of participants, response rate, type of data collection, number of sharps injuries, type of reporting of sharps injuries, number of participants, number of operations, average number of persons present in operations, total number of gloves used, and follow-up time.

Assessment of risk of bias in included studies

We assessed the risk of bias in a study based on study design adapted from Shamliyan et al.[16] We rated prospective studies, including RCTs, as the most valid designs to have a low risk of bias, retrospective studies as the most valid design to have a medium risk of bias, and cross-sectional studies as the most valid design to have a high risk of bias. We already excluded studies with a reference period of longer than 1 year and therefore did not rate this item for further risk of bias. We did not know in advance how to rate self-reported injury, administrative data-based injuries, or perforations, as these all have their respective flaws. Therefore, we did not add any extra items in our risk of bias assessment beyond study design.

Measures of the incidence of sharps injuries

We calculated the risk or the incidence of exposure to sharps injuries as the number of events divided by the amount of person-time at risk.[15] For the number of events, we made a distinction between self-reported and administrative data–based sharps injuries, but we did not further subdivide these categories. In addition, we used the number of perforated gloves or the number of perforations in gloves as proxy measures for sharps injuries.

For the population-time at risk, we used the number of py that participants were observed to document sharps injuries. In addition, we calculated a similar measure related to the number of operations in which study participants were involved, which we coined person-operations (po). For example, if 3 members of the surgical staff were observed to document sharps injuries in 150 operations, they contributed 450 po to the population at risk. We also used the number of gloves as an indicator of the population at risk.

We transformed all risk indicators into the number of sharps injuries per 100 units of population-time at risk such as per 100 py or per 100 po or per 100 pairs of gloves. It was not always clear whether the authors meant single gloves or pairs of gloves when they reported the number of gloves used. We made a judgment on which it must have been based on the context.

This resulted in the following measures of the incidence of sharps exposures: self-reported sharps injuries per 100 py and per 100 po, administrative data–based sharps injuries per 100 py and per 100 po, and perforated glove pairs per 100 py and per 100 po and per 100 glove pairs.

Dealing with missing data

We asked authors for additional information when we were unsure about the data from the article. We received a response from Makama et al.[17]

Assessment of heterogeneity

We assessed if studies were similar enough to be combined and decided that self-reported injuries, administrative data–based injuries, and perforations yielded such different results that they could not be combined. We also considered person-time and operation-time too different to be combined. In addition, we considered all surgical staff as similar enough to be combined. We calculated statistical heterogeneity as the I^2 value. We considered values higher than 75% as substantial heterogeneity.

Assessment of reporting biases

We assessed publication bias based on a funnel plot and conducted the Egger test.

Data synthesis

We used the natural logarithm of the incidence rates as input for the meta-analysis of studies that we considered sufficiently similar to be combined. We calculated the standard error of these rates as the inverse of the square root of the number of events (1/n^2). Based on these data, we then performed a random effects meta-analysis in STATA 13 (StataCorp, College Station, TX).

Subgroup analysis and investigation of heterogeneity

To enable a meaningful analysis, we used the best available outcome for each study in the following order: perforations per 100 po, self-reported injuries per 100 po, administrative data–based injuries per 100 po, self-reported injuries per 100 py, and administrative data–based injuries per 100 py. If a study did not report perforations per 100 po, we used the next best self-report per 100 po and so on.

We constructed the following meaningful subgroups to perform subgroup meta-analyses and meta-regression: type of outcome measurement as defined earlier, study design (RCT and prospective, retrospective follow-up, and cross-sectional), specialty (all staff of all specialties, 7 different specialties), continent (Europe, North America, Asia, Africa, and South America), and time period (before the year 2000, 2000-2009, after 2010). We used the metareg command in STATA 13. In the final multivariate meta-regression, we did not include the time period because the model could not handle so many variables.

Sensitivity analysis

We assessed if study designs with a higher risk of bias influenced our findings by assessing the incidence rates according to study design.

RESULTS

Results of the search

Our search resulted in 860 references. We found 7 additional articles from the Cochrane Database of Systematic Reviews on sharps injury prevention. We selected 122 articles for full-text assessment. Of these, 48 articles fulfilled the inclusion criteria, and 3 articles each referred to the same study. Therefore, we included a total of 45 studies (Supplementary Appendix S2).

Description of included studies

The data collection was started between 1990 and 2000 in 9 studies, between 2000 and 2010 in 24 studies, and between 2010 and 2018 in 12 studies. Geographically, 12 studies were conducted in the United States and 1 in Canada, 5 in the United Kingdom and 7 in other European countries, 5 in Nigeria and 2 in other African countries, 11 in Asia, and 2 in South America. In Table 1, the median number of self-reported sharps injuries across studies was 107 (interquartile range [IQR], 27-158); for administrative data–based sharps injuries, the median was 93 (IQR, 51-205); and for glove perforations, the median was 30 (IQR, 18-79). The median number of participants was 160 (IQR, 77-253); for included operations, the median was 200 (IQR, 110-2,877); and for the number of gloves, the median was 906 (IQR, 200-1,100). The mean follow-up time was 2 years (SD, 2).

Of the included studies, 11 were RCTs, 9 were prospective follow-up studies, 6 were retrospective follow-up studies, and 19 were cross-sectional studies. In 21 studies, the authors used a self-report of injuries with a questionnaire or interview, in 15 studies they

Table 1
Characteristics of included studies (N = 46)

Study ID	Country	Start year	Design	Hospitals (N)	Resp rate (%)	Disciplines	No. of sharps (SR)	No. of sharps adm	No. of sharps Perf	No. of r persons	No. of operations	No. of gloves	Ref years
Aarnio 2001[20]	Finland	1999	RCT	1	nr	Vasc S	—	—	12	—	37	134	0.2
Adams 2010[21]	UK	2009	CS	1	53	All staff	67	11	—	136	—	—	1
Adesunkanmi 2003[22]	Nigeria	1997	PC	1	nr	All S	56	—	—	589	572	—	2
Argentero 2006[23]	Italy	1999	PC	47	90	All S	9	—	—	100	—	—	1
Arowolo 2014[24]	Nigeria	2009	PC	1	nr	All S, A	—	—	152	150	1,050	16,800	4
Bali 2010[25]	India	2009	PC	1	nr	Oromax T	40	—	—	12	199	—	1
Barbosa 2004[26]	Brazil	2001	PC	1	nr	Plastic S, A	—	—	80	240	200	1,100	1.3
Bernard 2013[27]	US	2012	CS	1	66	Orthop S, A	10	—	—	40	—	—	1
Brasel 2007[28]	US	2001	RC	1	nr	All A	—	118	—	—	23,472	—	7
Dement 2004[29]	US	1998	RC	1	nr	All S	—	47	—	117	—	—	5
Ersozlu 2007[30]	Turkey	2004	PC	1	nr	All staff	—	—	206	604	200	906	1
Ertem 2008[31]	Turkey	2007	PC	1	nr	All staff	118	—	—	236	1,988	—	0.3
Foust-Wright 2017[32]	US	2016	CS	1	74	Obst S	26	—	—	44	—	—	1
Ganczak 2012[33]	Poland	2009	CS	16	70	S + Obst S, N	1,365	—	—	503	—	—	1
Ghauri 2011[34]	UK	2004	RC	13	nr	Ophthalm S, N	—	68	—	—	61,322	—	6
Haines 2011[35]	Canada	2005	CS	2	47	All S, A	512	—	—	155	—	—	1
Kerr 2009[36]	UK	2008	CS	3	82	All S	120	—	—	164	—	—	1
Khatony 2015[37]	Iran	2012	CS	1	78	All S	5	—	—	29	—	—	0.5
Korniewicz 2012[38]	US	2011	PC	3	68	All staff	—	—	748	702	4,580	29,071	2
Kovavisarach 2002[39]	Thailand	1999	RCT	1	nr	Gynec S	—	—	20	—	88	176	1
Laine 2001[40]	Finland	1999	RCT	1	nr	All S	—	—	76	—	443	1,020	0.2
Lakbala 2014[41]	Iran	2013	CS	14	86	All staff	709	—	—	215	—	—	1
Leavy 2017[42]	UK	2015	CS	1	63	Oromax S, A, N	5	—	—	55	—	—	1
Makama 2010[43]	Nigeria	2013	RCT	1	100	All S, A	—	—	78	—	54	1,024	1.6
Mohammad 2014[44]	US	2000	RC	1	nr	All S, A	—	228	—	280	—	—	8.0
Myers 2008[19]	US	2001	CS	1	nr	All staff	—	338	—	—	60,583	—	2
Myers 2016[45]	US	2001	RC	1	nr	All staff	—	1983	—	—	317,416	—	10
Nagao 2009[46]	Japan	2000	RC	1	nr	All S, N	—	136	—	851	—	—	8
Naver 2000[47]	Denmark	1999	RCT	1	nr	All staff	—	—	53	—	102	712	
Nordkam 2005[48]	Netherlands	2004	RCT	1	nr	Abd S, A	—	—	28	—	100	200	1
Nwankwo 2011[49]	Nigeria	2011		3	80	All A	107	—	—	184	—	—	0.5
Olatosi 2016[50]	Nigeria	2016	PC	3	81	All staff	173	—	—	274	—	—	1
Phillips 2007[51]	Sub Saharan Africa	2006	CS	v	76	All S	260	—	—	84	—	—	1
Punyatnansakchai 2004[52]	Thailand	2002	RCT	1	nr	All staff	—	—	3	—	150	300	0.7
Stitely 2009[53]	US	2008	RCT	1	99	All staff	—	—	30	—	123	1,410	1.2
Stringer 2002[54]	US	1995	CS	1	nr	All staff	143	—	—	—	3,765	—	0.5
Sukhraj 2015[55]	Trinidad and Tobago	2015	CS	1	nr	All A	23	—	—	40	—	—	1
Sullivan 2009[56]	US	2005	RCT	1	nr	Obst S	—	—	17	—	97	—	1.7
Tarantola 2005[57]	West-Africa	1991	CS	v	nr	All staff	219	—	—	192	—	—	1
Tarantola 2006[58]	France	2000	CS	20	76	All S	140	—	—	257	—	—	0.1
Thomas 2001[59]	India	2001	RCT	1	nr	All S, A	—	—	19	—	33	132	nr
Thomas 2009[60]	UK	2009	CS	1	77	All S	111	—	—	75	—	—	0.5
Wilson 2008[61]	US	2005	RCT	1	nr	Obst S	—	—	5	—	221	—	1.7
Yonezawa 2015[62]	Japan	2006	CS	1	nr	All staff	—	63	—	210	—	—	6
Zhang 2009[63]	China	2004	CS	1	nr	All staff	28	—	—	57	—	—	1

A, assistants, including residents and trainees; *Abd*, abdominal surgery; *Adm*, administrative-based report; *CS*, cross-sectional study; *Gynec*, gynecology; *ID*, identifier; *N*, nurses; *nr*, not reported; *Obst*, obstetrics; *Oromax*, oral and maxillofacial; *Ophthalm*, ophthalmic; Orthop, orthopedic; *PC*, prospective cohort; *Perf*, perforations; *RC*, retrospective cohort; *RCT*, randomized controlled trial; *Resp rate*, response rate; *S*, surgeons; *Vasc*, vascular; *SR*, self-report; *T*, technical staff; *UK*, United Kingdom; *US*, United States.

Table 2
Results of meta-analyses of studies (n = 45) that report incidence of sharps injuries in surgical units overall and according to outcome measure

	No. of studies	Injury rate	95% CI	I^2 (%)	Tau-square
Self-report					
Per 100 py	21	88.2	61.3-126.9	99.2	0.67
Per 100 po	4	2.1	0.8-5.0	98.5	0.82
Administrative reports					
Per 100 py	5	5.8	2.7-12.2	98.3	0.70
Per 100 po	4	0.1	0.05-0.21	99.4	0.56
Perforations					
Per 100 py	15	40.0	19.2-83.5	99.4	2.06
Per 100 po	15	11.1	6.6-18.9	98.8	1.04
Per 100 glove pairs	13	11.7	6.3-21.6	99.1	1.23
Best available outcome per study					
Per 100 time-units	45	13.2	4.7-37.1	100	12.39

CI, confidence interval; I^2, percentage of variation across studies due to heterogeneity; *po*, person-operations; *py*, person-years; *Tau-square*, absolute value of variance owing due to heterogeneity.

collected gloves, and in 9 studies they used administrative data. In 16 studies using questionnaires, the response rate was on average 68% with a range from 47%-90%.

Participants in the studies were all surgical staff in 14 studies, surgeons only in 15 studies, trainees or assistants in 4 studies, and any combination of surgeons and other staff in the remaining 12 studies. Ten studies were conducted with staff from the following specialties only: 4 in gynecology and obstetrics; 2 in oral-maxillary surgery; and 1 each in ophthalmology, plastic surgery, vascular surgery, and orthopedic surgery. Participants came from 1 hospital only in 33 studies and on average from 10 hospitals in the other 12 studies.

Description of excluded studies

Most studies were excluded because they were reported before the year 2000. In another large proportion of excluded studies, there were no data about the population at risk or the study was not focused on surgical staff or reported a mix of sharps injuries and blood and fluid splashes.

Incidence of sharps injuries

The injury rates according to type of reporting and type of person-time at risk are reported in Table 2. Rates per 100 po are substantially lower than the rates per 100 py. Administrative data yielded the lowest rates, whereas glove perforations produced a higher rate and self-report generated the highest rate of all. The calculation of perforations per 100 glove pairs yields very similar results to the calculation per 100 po. There is substantial variation between studies, as all I^2 values were above 90%.

The funnel plot did not indicate publication bias, and the Egger test was nonsignificant (bias coefficient = 8.8; $P = 0.44$)

Subgroup analysis and meta-regression

The results of meta-analysis with the best available outcome per study according to subgroups of outcomes are reported in Figure 1.

The results of the meta-regression (available on request from the authors) indicate lower rates in studies with self-reported injuries per 100 po (meta-relative risk [RR], 0.19; 95% CI, 0.05-0.64) and higher rates in studies with self-reported injuries per 100 py (meta-RR, 8.10; 95% CI, 3.72-17.62). There were also lower rates in studies with a retrospective cohort design (meta-RR, 0.15; 95% CI, 0.02-0.96), as well as in studies conducted in North America (meta-RR, 0.15; 95% CI, 0.03-0.92) and in studies conducted among ophthalmologists (meta-RR, 0.002; 95% CI, 0.00-0.24). However, in the multivariate analysis, only the higher rates of self-reported injuries over person-time remained significant.

DISCUSSION

Summary of the main results

We located 45 studies that reported the incidence of sharps injuries in surgical staff in varying ways. Glove perforation rates per 100 po were about 8 times lower than self-reported injuries per 100 py in the meta-analysis of 15 and 21 studies, respectively. In addition, perforation rates per 100 po were 4 times lower than perforations per 100 py in a meta-analysis of 15 studies. Overall, the best available estimate over the 45 studies was 13.2 injuries per 100 person-time units. There seemed to be lower perforation rates in North America than in other countries, and the rates were not significantly different over time. Ophthalmologists had lower rates than physicians in other specialties.

Strengths of the study

The strength of our study is that we calculated very carefully similar injury metrics from what the authors of other studies have reported. We then only pooled the results of similar metrics in the meta-analyses. We categorized the types of injury measurement into self-reports, use of administrative data and glove perforations, and the measure of the population at risk into person-time and po. This reduced the variation in reporting of injuries. The use of po seems to be a more realistic measure of the population at risk than person-time. This probably reflects the fact that the risk only occurs during operations and that the number of operations can vary between surgeons. The reporting of glove perforations also seems to be more realistic than the self-reporting of injuries. We found in earlier studies that when asked to estimate demanding tasks such as lifting or pushing, workers tend to overestimate the duration and frequency of these tasks compared with more objective observations.[18] We assume that there is a similar recall mechanism at work with self-report of sharps injuries. We expected the perforation rates to be higher than the rates of self-reported injuries because the testing of gloves is very sensitive and will detect holes even in unused gloves. However, in the meta-regression, the rate of self-reported injuries per 100 py was 7 times higher than the rate of perforations per 100 po. In our view, this can only mean that self-reports do not give a reliable indication of the real risk and probably overestimate it.

We included all studies, without language restrictions. Native speakers assessed the inclusion and helped with the data extraction of 2 studies.

Five studies were published in multiple articles. Considering that we included studies and not articles in our review, these multiple reports did not influence our findings inappropriately.

Limitations of the study

Even though we took great care in extracting the correct data from studies, this might not always have succeeded. The reporting of studies was very often ambiguous, such as the reporting of the number of gloves. Even after extensive e-mail communication with 1 author, we were unsure whether we understood what the author had done in that study. With the word “gloves,” authors could mean the absolute total number of single gloves or the number of glove pairs. We had to make an assessment, which was the case in that study based on reported data such as the number of persons and operations involved. Given that for most studies the number of glove pairs used and the

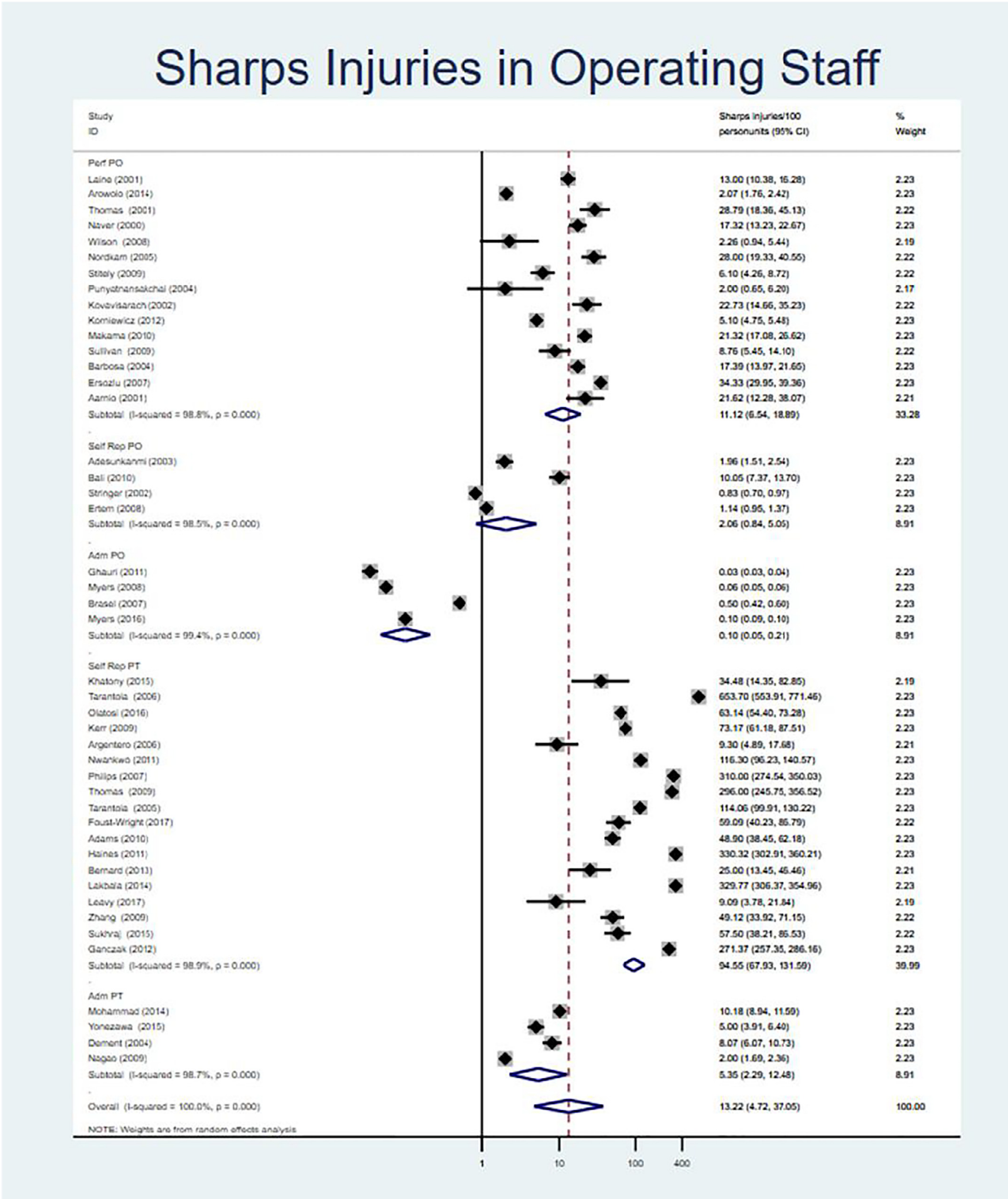

Fig 1. Forest plot of meta-analysis of 45 studies of incidence of sharps injuries per subgroup of incidence measure and overall. Perf PO, Perforations per 100 person operations, Self Rep PO, self reported injuries per 100 person operations, Adm PO, administrative reports per 100 person operations, Self Rep PT, self reported injuries per 100 person years, Adm PT, administrative reports per 100 person years, Weight, weight of the studies in the meta-analysis.

number of persons involved in operations yielded similar results, we apparently succeeded fairly well in our estimations.

The authors frequently reported the number of injuries per operation without being clear on how many persons were involved in the operations. Considering that the average number of persons involved in operations varied from 1-7, this would also have influenced the injury rate with the same variation. Therefore, we did not calculate the rate per operation but per person-operation. Even though this seems to be a big improvement over injury rates per py, this could possibly be further improved by taking operation time into account and calculating the risk per po hours. There was 1 study that used this measure.[19] However, it is unclear how much this would improve the injury rates over po given that there is not very large variation in duration of operations.

The use of perforations was also not unequivocal but could mean a perforated glove and the total number of perforations in both gloves. Even though we did our best to find out which was the case, we might not always have succeeded, and this could explain a part of the unexplained heterogeneity.

Our subgroup analysis is based on characteristics of studies at the study level. This can lead to the same bias as in ecological studies. These analyses should therefore be considered exploratory. Even though tests for subgroup differences usually lack power, all subgroups were significantly different from the pooled result.

Implications for practice

The baseline risk of a sharps injury for a member of surgical staff is probably about 13 injuries per 100 po, which means that a surgeon will have a sharps injury in about 1 in 10 operations. Self-reports are probably an overestimation of the risk, and it is best to use glove perforations as an indicator of sharps injuries. Person-time is not a reliable measure of time at risk, and it is better to use po. Injury rates in North America might be lower than elsewhere. Ophthalmologists have lower-than-average sharps injury rates.

Implications for research

Variation in incidence rates of sharps injuries among surgeons can be reduced by using objective measures such as glove perforation rates as indicators of injury and po for the population at risk. The baseline rates provided in this review can be used to assess burden of disease and the cost-effectiveness of preventive measures such as double gloving, blunt needles, or safe working techniques. Considering that the perforation rates provided here are much lower than the self-reported injuries used to calculate the burden of disease due to sharps injuries by the WHO, these calculations should be revised. Future studies should explore if the use of po time can further reduce heterogeneity. Predictors of injuries should be explored by systematically reviewing studies that compare the injury risk in a standardized way between different disciplines of surgical staff, types of operations, durations of operations, and timing of operations.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ajic.2018.10.003.

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