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Burden of insulin injection-related needlestick injuries in mainland China–prevalence, incidence, and healthcare costs

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ABSTRACT

Objective: To estimate the prevalence and incidence of needlestick injuries associated with insulin injection among nurses working in hospitals in China and to quantify the direct healthcare costs associated with insulin injection-related needlestick injuries.
Methods: We conducted a large online survey among hospital nurses from 31 provinces, municipal cities, and autonomous regions in China from October 2016 to February 2017. The survey covered a wide range of questions, including geographical location, years of experience, insulin injection practice, number of insulin injection-related needlestick injuries in the past 12 months, interventions for needlestick injuries, and treatment costs. We developed a cost estimate model and categorized costs into two major components: infection prevention and treatment of infections.
Results: We received a total of 10,447 questionnaires, of which 9873 were complete and validated. 39.1% of the nurses reported at least one needlestick injury while administering diabetic injections at some point in the past. The incidence of needlestick injuries involving injection pens was 139.5 per 1000 nurses per year and, with adjustment for exposure, 10.2 needlestick injuries per 100,000 injections. Among the respondents, 3.2% reported of having hepatitis B virus infection and 0.9% having hepatitis C virus infection as a result of needlestick injuries. The total costs of one insulin injection-related needlestick injury was estimated to range from ¥1,884 - ¥2,389.
Conclusions: Insulin injection-related needlestick injuries were common in nurses working in hospitals in China and imposed a significant economic burden. More resources should be allocated for preventive efforts for needlestick injuries, including adoption of injection devices with advanced safety features.

What is already known about the topic?

- About 3.8 million sharp injuries occurred among health care workers in hospitals in mainland China each year and 63.0% of these injuries were caused by hollow-bore needles.
- A study reported that insulin injection pen-related injury was the most common injury, accounting for 26% of all sharp injuries.
- Few studies have been conducted about incidence rates of needlestick injuries (NSIs) and economic burden associated with insulin injection-related NSIs in China.

What this paper adds

- Insulin injection-related NSIs were common in nurses working in hospitals in China.
- Insulin injection-related NSIs imposed a significant economic burden in China.

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- More resources should be allocated for preventive efforts for NSIs, including adoption of injection devices with advanced safety features.

1. Introduction

Needlestick injuries (NSIs) pose a significant occupational health risk to health care workers. There are over 25 life-threatening pathogens that can be transmitted via needles (Tarantola et al., 2006). Worldwide, percutaneous injury with mainly NSI is implicated in approximately 1000 new human immunodeficiency virus (HIV) infections, 66,000 new hepatitis B virus (HBV) infections, and 16,000 new hepatitis C virus (HCV) infections each year (Prüs-Üstün et al., 2005). It has been estimated that about 3.8 million sharp injuries occurred among health care workers in hospitals in mainland China each year and 63.0% of these injuries were caused by hollow-bore needles (Gao et al., 2017). For nurses, sharp injuries caused by hollow-bore needles were even higher accounting for 76.7% of all sharp injuries. Results from a separate study based on a sharp injury registry in China reported that insulin injection pen-related injury was the most common injury, accounting for 26% of all sharp injuries (Zhao et al., 2011).

In China, the prevalence of diabetes and prediabetes has been increasing rapidly with 11.6% of the adult population today having this condition (Xu et al., 2013). For decades, insulin was delivered only via vials and syringes with larger bore needles. A study conducted in China showed that syringe needles ranked at the top of all NSIs according to type of devices (Zhang et al., 2015a). Compared with the vial/syringe system, injection pens have multiple advantageous features, including but not limited to, ease of use, reduced the needle phobia, lower barriers in initiating insulin therapy, ease in transport and discreet use, and greater accuracy in insulin dosage (Asamoah, 2008). Numerous studies have confirmed that these benefits are associated with patient preference, treatment satisfaction, significant reduction in health care resource utilization, improved treatment adherence, reduced likelihood of experiencing a hypoglycemic event, and achieve better glycemic control (Korytkowski et al., 2003; Lee et al., 2006; Niskanen, 2010; Pawaskar et al., 2007). Findings from the recent worldwide insulin injection survey involving 13,289 diabetic patients (29% were Chinese patients) from 42 countries showed that 85.6% of patients used injection pen alone at the outpatient settings (Frid et al., 2016). However, there is limited data in literature on insulin administration practice at hospital settings and the occurrence of NSIs associated with insulin injections in health care workers. We also found no study documenting the economic burden attributable to insulin injection-related NSIs in China. The primary aim of this survey was to estimate risk of NSIs associated with insulin injection, focusing on injection pens, among nurses working in hospitals in China. The secondary aim was to quantify direct healthcare costs associated with insulin-injection related NSIs.

2. Materials and methods

We conducted a cross-sectional survey among nurses, senior nurses, nurses-in-charge and chief nurses/deputy chief nurses in endocrinology and other departments in 31 provinces, municipal cities, and autonomous regions in China. The survey was designed with experts' inputs on the standard procedures for responding to insulin injection-related NSIs. The survey was fulfilled via an online survey platform (Wen Juan Xing®: http://www.wjx.cn) from November 2016 to February 2017. The study was approved retrospectively by the Institutional Review Board (IRB) as no explicit requirement for anonymous surveys involving only healthcare professionals at the study planning stage (the detail information of ethical approval could be found at the end of the article). We conducted a pilot testing (n = 25) at a tertiary teaching hospital and refined the questionnaire based on the pilot. The final survey questionnaire is composed of 85 questions on characteristics of the hospitals, working experience of the respondents, insulin injection practice, insulin injection-related NSIs, infections from NSIs and their treatments, and costs of treating NSIs. Before the survey was fielded, we conducted study trainings for the chief/lead nurses of participating hospitals with topics covering the survey purpose, participant eligibility, methods, contents, duration of the study, length of time taken for completing the survey, etc. Upon completing the training, the chief/lead nurses invited eligible participants in their respective institutions to fill out the survey, which comprised brief description of the survey as instructed at the training and the QR code leading to the web-based survey questionnaire. The participants were further informed of this voluntary survey by reading through the introduction section of the survey questionnaire, which adds additional context of the survey, the purpose, and gratefulness for their participation. The survey took about 10 minutes to complete and no financial incentives were provided. Each participant can only complete survey once as the QR code linking prevented duplicate surveys. All completed questionnaires were validated in cross-referencing with pre-determined acceptable values per experts' input. As our study focuses on insulin injection-related NSIs, we excluded respondents who reported zero insulin injection per week in this analysis. All statistical analyses were conducted in R 3.4.3 (R Core Team, 2017). The economic model was developed in Microsoft® Excel 2016.

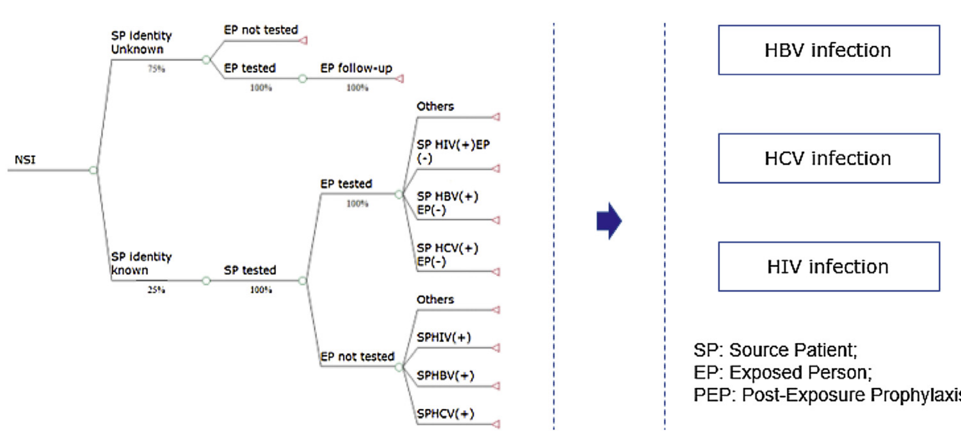

Fig. 1. Schematic Diagram for Direct Healthcare Cost Estimate.

We made inquiries of experiencing NSIs from the survey respondents both sometime in the past and in the past 12 months. Study participants could have experienced multiple NSIs over the past year. We used cumulative incidence as a measurement of risk, which was defined as the total number of NSIs per 1000 nurses per year. To account for the exposure risk, i.e., frequency of using different injection devices, we also estimated annual number of NSIs per 100,000 insulin injections by injection pens. Each respondent was asked to report average number of insulin injections with injection pens that they administered per week in the past year, and number of insulin injection-related NSIs associated injecting pens. The incidence of NSIs per year was calculated in two ways. 1) Annual NSIs per 1000 Nurses = (total number of NSIs of using the insulin pens) / (total number of participants) * 1000; 2) Number of NSIs per 100,000 Injections = (total number of NSIs of using the insulin pens) / (total number of injections with insulin pens).

To estimate direct healthcare costs associated with insulin injection-related NSIs, we developed a cost estimate model as illustrated in Fig. 1. We categorized the direct healthcare costs into two major components: 1) costs to prevent infections post NSIs, including lab tests right after NSIs, post-exposure prophylaxis and ensuing lab tests and 2) costs of treatment of infections as needed. Only treatment costs associated with NSIs incurred during the first year were included. We assumed that, in the event of NSIs, the health care professionals would undergo several lab tests (Glenngård and Persson, 2009). We also presumed that the rate of testing exposed people after NSIs was 100% when estimating the costs associated with NSIs. In addition, we assumed that post-exposure prophylaxis after HBV or HIV exposure conferred complete protection. We constructed three scenarios using different data sources for parameter estimate. Scenario one: post-exposure prophylaxis, ensuing lab tests, infection risks, and costs of treatments all derived from literature; scenario

Table 1
Data Sources and Values for Healthcare Costs Estimate Associated with Insulin Injection-related NSIs in 2017.

Parameter	Scenario One		Scenario Two		Scenario Three	
	Value	Source	Value	Source	Value	Source
Rate						
Prevalence of HBV among diabetics	13.5%	Lu et al., 2017	13.5%	Lu et al., 2017	13.5%	Lu et al., 2017
% susceptible to HBV among health care professionals	29.8%	Yang et al., 2011	29.8%	Yang et al., 2011	29.8%	Yang et al., 2011
Prevalence of HCV among diabetics	6.5%	Wang et al., 2008	6.5%	Wang et al., 2008	6.5%	Wang et al., 2008
% susceptible to HCV among health care professionals	98.8%	Yang et al., 2011	98.8%	Yang et al., 2011	98.8%	Yang et al., 2011
Prevalence of HIV among diabetics	0.06%	Huang et al., 2015	0.06%	(Huang et al., 2015)	0.06%	(Huang et al., 2015)
% susceptible to HIV among health care professionals	99.9%	Huang et al., 2008	99.9%	Huang et al., 2008	99.9%	Huang et al., 2008
Infection risk of HBV	1.2%	Hanmore et al., 2013; Lu et al., 2017; Yang, 2011	3.2%	Survey	3.2%	Survey
Infection risk of HCV	0.12%	Hanmore et al., 2013; Yang et al., 2011; Wang et al., 2008	0.9%	Survey	0.9%	Survey
Infection risk of HIV	0.00018%	Hanmore et al., 2013; Huang et al., 2008, 2015	0.0%	Survey	0.0%	Survey
SP identity known percent	75.0%	(Glenngård and Persson, 2009)	75.0%	(Glenngård and Persson, 2009)	75.0%	(Glenngård and Persson, 2009)
Percentage of EP tested	100%	Assumption	100%	Assumption	100%	Assumption
Costs (¥)/($)						
Costs of testing exposed people in all cases	883(131)	Survey	883(131)	Survey	883(131)	Survey
Costs of testing SP in SP known cases	807(120)	Survey	807(120)	Survey	807(120)	Survey
Costs of follow-up exposed people when SP is HBV positive*	1307(194)	Unpublished data□,□	1307(194)	Unpublished data□,□	987(146)	Survey
Costs of follow-up exposed people when SP is HCV positive*	1810(268)	Unpublished data□,□	1810(268)	Unpublished data□,□	568(84)	Survey
Costs of follow-up exposed people when SP is HIV positive*	1988(295)	Unpublished data□,□	1988(295)	Unpublished data□,□	1840(273)	Survey
Annual treatment costs of HBV	25,028 (3708)	(Hu and Chen, 2009)	25,028 (3708)	(Hu and Chen, 2009)	61,745 (9147)	Survey
Annual treatment costs of HCV	69,280 (10264)	Liu et al., 2011	69,280 (10264)	Liu et al., 2011	69143 (10243)	Survey
Annual treatment costs of HIV	17126 (2537)	Zhang et al., 2015a	17126 (2537)	Zhang et al., 2015b	49409 (7320)	Survey
Percentage of HBV became chronic and generate cost	7.5%	(Paul Leigh et al., 2007)	7.5%	(Paul Leigh et al., 2007)	7.5%	(Paul Leigh et al., 2007)
Percentage of HCV became chronic and generate cost	85%	(Paul Leigh et al., 2007)	85%	(Paul Leigh et al., 2007)	85%	(Paul Leigh et al., 2007)
Unit cost of follow-up when SP is unknown	359(53)	Unpublished data□; Glenngård and Persson, 2009	359(53)	Unpublished data□ (Glenngård and Persson, 2009)	359(53)	Unpublished data□ (Glenngård and Persson, 2009)
Times of follow-up tests when SP is unknown	2	(Glenngård and Persson, 2009)	2	(Glenngård and Persson, 2009)	2	(Glenngård and Persson, 2009)

SP: Source Patient; PEP: Post-Exposure Prophylaxis.
* including the cost of PEP.
□ Fudan University Zhongshan Hospital, 2014. Standard operating procedure for occupational exposure treatment in healthcare workers.
□ Compilation of healthcare service items and costs in Shanghai (2014), Chengdu (2016), Liaoning (2017) and Beijing (2017).

two: post-exposure prophylaxis, ensuing lab tests, and costs of treatment derived from literature while infection risks derived from our survey; and scenario three: post-exposure prophylaxis, ensuing lab tests, infection risks, and costs of treatments all derived from our survey. To assess impact of individual variables on the estimate of total costs, we conducted a series of one-way sensitivity analyses for all parameters by varying ±20% their mean values in the three scenarios. Where appropriate, the costs are displayed in both Chinese currency (Yuan: ¥) and USD ($) at the conversion rate of 1$ = 6.75¥ in 2017.

The lab tests needed for source patients and exposed people right after insulin injection-related NSIs in all scenarios were derived from the survey. Unit costs of lab tests and post-exposure prophylaxis were estimated by the mean value of unit costs in Shanghai, Liaoning, Beijing, and Sichuan in China (Unpublished data□). In scenario one, we applied the transmission probability of HBV, HCV, and HIV at 30%, 1.8%, and 0.3% for susceptible persons (Hanmore et al., 2013) and estimated the respective infection risk of HBV, HCV, and HIV as follows.

Infection Risk = Transmission Probability * Prevalence of Infection (source patient) * Susceptible (health care professionals) *100%

The data source for each scenario is presented in Table 1.

3. Results

In total, we received 10,447 questionnaires, of which 9873 (completion rate 94.5%) were validated and included in our analyses. The mean age of the respondents was 29.7 years old. Hunan Province accounted for 40.4% of validated surveys and all other regions contributed less than 10% of the total questionnaires received and analyzed. The working profiles of study participants are presented in Table 2. The respondents worked predominately in tertiary care hospitals (92.4%) and about one third were affiliated with endocrinology department. Slightly over half of respondents had more than 5 years of nursing experience and the vast majority (88.6%) reported receiving training on injection safety at work.

3.1. Prevalence and incidence of insulin injection-related NSIs and infections

Among the respondents, 39.1% reported experiencing at least one insulin injection-related NSIs at some point in the past. Injection pens were implicated at the rate of 139.5 per 1000 nurses per year (Table 3). When the incidence were estimated by injection frequency, use of insulin injection pens was associated with 10.2 NSIs per 100,000 injections. Slightly over 80% of injection pen-related NSIs were front-end related.

Among respondents who experienced one or more prior insulin injection-related NSIs, 3.2% reported HBV infections and 0.9% had HCV infection as a result of NSIs. No HIV infection was reported.

3.2. Economic burden of insulin injection-related NSIs

The estimated direct healthcare costs associated insulin injection-related NSIs are presented in Table 4. In all scenarios, costs of lab tests and post-exposure prophylaxis accounted for greater than three quarters of total costs and varied little across different scenarios. On the other hand, costs associated with infection treatment varied greatly from ¥90 in scenario one to ¥664 in scenario three. The total cost of each insulin injection-related NSIs ranged from ¥1884 - ¥2389.

Results of one-way sensitivity analyses for ±20% variation in the three scenarios are presented in Supplementary Figure 1–3 (top 15 most influential factors were presented). The variable with the single largest influence on the total costs estimate for scenario one and three is the costs of testing exposed people while that in scenario two is the costs of testing SP in SP known cases.

Table 2
Working Profiles of the Study Participants.

Characteristics	N (%)
Hospital type	
Primary	364 (3.7)
Secondary	386 (3.9)
Tertiary	9123 (92.4)
Department	
Endocrinology	3203 (32.4)
Internal medicine (Other than endocrinology)	2351 (23.8)
Surgical	1860 (18.8)
Emergency	200 (2.0)
Operating room	15 (0.2)
Infectious disease	171 (1.7)
ICU	371 (3.8)
Pediatrics	135 (1.4)
Obstetrics and gynecology	345 (3.5)
Other	1222 (12.4)
Professional title	
Nurse	2803 (28.4)
Senior nurse	4574 (46.3)
Nurse-in-charge and above	2168 (22.0)
Other	328 (3.3)
Years of experience	
Intern/resident	347 (3.5)
≤2 years	1688 (17.1)
3-5 years	2379 (24.1)
6-10 years	2781 (28.2)
11-19 years	1808 (18.3)
≥20 years	870 (8.8)

Table 3
Annual Incidence of NSIs Associated with Use of Insulin Injection Pens.

Incidence	Total	Front-end-related	Back-end-related
Annual NSIs per 1000 Nurses	139.5	114.1	25.4
# of NSIs per 100,000 Injections	10.2	8.3	1.9

4. Discussion

Our study was the first large-scale survey on the burden of insulin injection-related NSIs for hospital nurses in China, covering a total of 31 provinces, municipal cities, and autonomous regions. About 39.1% of nurses experienced at least one insulin injection-related NSI at some point in the past. Among our survey respondents, the risk of HBV and HCV infection was 3.2% and 0.9%, respectively. The direct cost of one insulin injection-related NSI was estimated to range from ¥1884 - ¥2389 ($279 - $354).

A number of studies have estimated NSIs in different countries (Costigliola et al., 2012; Lee et al., 2005). While the findings consistently indicated that NSIs were a major health hazard to health care workers, it is difficult to compare NSIs statistics from different studies directly as each study tended to use different definitions for risk measurement and none of these studies examined the device-specific risk of NSIs by unit of exposure. Previous research on risk of sharp injuries in China revealed that 7.8% of all nurses surveyed declared at least one sharp injury (the majority were caused by hollow-bore needles) in the previous month (Gao et al., 2017). It was unknown what percentage of the reported sharp injuries in this study involved insulin injections. In addition, this study included nurses from all specialty areas and traditional syringes were most commonly used for injections. Another study conducted in China indicated that 64.9% of the

Table 4
Average Direct Healthcare Costs per Insulin Injection-related NSI.

Costs Sources (¥)	Scenario One ($)	Scenario Two ($)	Scenario Three ($)
Costs for lab tests right after NSI	1488 (220)	1488 (220)	1488 (220)
Costs for post-exposure prophylaxis and ensuing lab tests	306 (45)	306 (45)	237 (35)
Infection treatment	90 (13)	578 (86)	664 (98)
Total Cost	1884 (279)	2372 (351)	2389 (354)

nurses reported needlestick or sharp injuries during the past year. But the specific percentage involved insulin injections was not reported (Zhang et al., 2015b). In our survey, injection pens accounted for about two thirds of insulin deliveries. We also noted somewhat higher reported NSIs related infection for HBV and HCV (3.2% and 0.9%, respectively) vs. the estimates from others studies (1.2% and 0.12%, respectively) (Hanmore et al., 2013; Huang et al., 2015; Lu et al., 2017; Yang et al., 2011; Wang et al., 2008). It is worth pointing out that the risk of blood-borne infection reflects both the risk of NSIs and the infection prevalence of the source population.

The use of injection pens for insulin delivery has largely replaced traditional vial/syringe systems since the first insulin pen injector was introduced in the 1980s because of its many perceived benefits have been confirmed by numerous studies (Korytkowski et al., 2003; Lee et al., 2006; Niskanen, 2010; Pawaskar et al., 2007). The earlier versions of injection pen needles have no advanced safety features and NSIs associated with their use are a concern among health care workers and more so for diabetic care nurses who administer multiple doses of insulin as they are exposed daily and several times a day to the risk of unexpected NSIs with potentially contaminated needles. One of the most commonly implemented NSIs prevention programs is to provide training on injection safety. In our study, nearly 90% of the respondents reported having received safety training at work. However, even if all health care workers were trained on injection safety, it would be unrealistic to expect the safety training could reduce NSIs to null or to near null. Recently, safety-engineered injection pens have been introduced in many countries, which are engineered with both front and back-end needle protection. The safety mechanisms activate automatically after use to protect the device user from exposure to the sharp by covering the sharp immediately following use. Findings from a meta-analysis of 17 studies evaluating effectiveness of different NSIs prevention interventions concluded that, while training intervention can reduce risk of NSIs, the most effective intervention is combination of safety training and use of safety-engineered devices (Tarigan et al., 2015). As expected, the new safety-engineered devices are available at a higher acquisition cost, which may deter its adoption in hospital settings. However, decision on use of safety-engineered devices based on acquisition cost alone could be short-sighted. Findings from a budget impact analysis on adoption of safety-engineered sharp devices from the perspective of a Belgium hospital showed that cost savings from managing fewer NSIs more than offset increased device acquisition cost (Lee et al., 2006). Additional real-world evidence from a prospective observational study on evaluation of injection pens with advanced safety features vs. syringes demonstrated that, although insulin pens had higher acquisition cost than both traditional syringes and safety syringes, using injection pens with dual-ended protection were cost-savings when insulin supply and NSIs costs were taken into account (Centers for Disease Control and Prevention, 2008).

A number of studies have quantified the costs associated with NSIs. Orenstein et al estimated that the cost of one NSI in the United States (US), including costs for post-exposure prophylaxis, testing, and productivity loss, was approximately $260 (~¥7714 in 2017 Chinese currency) (Orenstein et al., 1995). O'Malley et al estimated that in US, the cost of one NSI ranged from $71 to $4838 (~¥763 to ¥51,993) taking into consideration costs for post-exposure prophylaxis (include other costs like counseling, treatment etc.) and lab testing (O'Malley et al., 2007). Glenngard et al considered costs for PEP, testing, and counseling, and estimated the cost of one NSI in Sweden to be approximately €272 (~¥2985) (Glenngård and Persson, 2009). Hanmore et al considered costs for post-exposure prophylaxis, testing, treatment of infections, and productivity loss, and estimated the direct cost of one NSI in Belgium ranging from €210 to €950 (~¥1841 to ¥8331) and the indirect cost from €63 to €844 (~¥554 to ¥7401) (Hanmore et al., 2013). Our cost estimates were similar to cost estimates from previous studies. It is worth noting that, in our study, the estimates of direct costs of NSIs for lab testing, post-exposure prophylaxis varied little with different scenarios, indicating the robustness of our estimates.

The results of our study should be interpreted in the context of study limitations. Like all surveys, respondents were asked to participate in the study on the voluntary basis and it was possible that nurses with prior NSIs were more likely to participate in the study, which could lead to overestimate the risk of NSIs. Although the study sample size was very large, the majority of respondents were from a few provinces. The results were heavily influenced by those provinces and may not be representative of the entire country. In our costing analysis, we only considered direct healthcare costs and the treatment costs for infections in the first year. Indirect costs due to productivity loss and healthcare costs in subsequent years may be large for some, and our conservative approach may have underestimated the true cost of NSIs.

5. Conclusion and recommendations

Insulin injection-related NSIs were prevalent among nurses working in hospitals in China and imposed significant economic burden. With the increasing prevalence of diabetes in China, the burden of NSIs will likely continue to grow in future. More resources should be allocated for preventive efforts for NSIs, especially among high-risk health care professionals. Such preventive efforts should include periodic safety training, encouragement of NSIs reporting, establishment of standard operating procedures, and use of injection devices with advanced safety features.

6. Originality

This article is an original work, has not been published before, and is not being considered for publication elsewhere in its final form, in either printed or electronic media. It is not based on any previous communication to a society or meeting. The two abstracts of this study were previously presented as posters at the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) 23nd Annual Meeting, May 19–23, 2018, Baltimore, MD, USA.

Author contributions

All authors met the authorship criteria set forth by the International Committee for Medical Journal Editors through direct contributions to the study, design, and protocol development. All authors had significant input in drafting and revising the manuscript for its intellectual content.

Informed consent

Per local policy, completion of anonymous surveys is considered implied consent.

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Ethical approval

The study was approved by Institutional Review Board (IRB) in China-Japan Friendship Hospital (center hospital) in November 2018 (Number: 2018-150-K107).

Conflict of interest

No conflict of interest has been declared by the authors. The study was sponsored by Becton Dickinson (BD) and no conflict of interest of the sponsor.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijnurstu.2019.05.006.

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