Needlestick injuries in a major teaching hospital: The worthwhile effect of hospital-wide replacement of conventional hollow-bore needles

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Background: Needlestick injury (NSI) with hollow-bore needles remains a significant risk of bloodborne virus acquisition in health care workers. The impact on NSI rates after substantial replacement of conventional hollow-bore needles with the simultaneous introduction of safety-engineered devices (SEDs) including retractable syringes, needle-free intravenous (IV) systems, and safety winged butterfly needles was examined in an 800-bed Australian university hospital.
Methods: NSIs were prospectively monitored for 2 years (2005-2006) after the introduction of SEDs and compared with prospectively collected preintervention NSI data (2000-2004).
Results: Preintervention hollow-bore NSI rates over 10 years persisted at a constant rate between 3.01 and 3.77 per 100 full-time equivalent employees (FTE) ($P = .31$). Rates for 2005 (1.93; 95% CI: 1.48-2.47 per 100 FTE) and 2006 (1.50; 95% CI: 1.11-1.97 per 100 FTE) were significantly lower than the average rate for the preintervention years (3.39; 95% CI: 2.7-4.24 per 100 FTE, $P = .00004$). This represents a fall of 49% (43.1%-55.7%) in hollow-bore NSI, contributed to by the virtual elimination of NSI related to accessing IV lines. More importantly, high-risk injuries were also reduced 57% by retractable syringe use with an overall budgetary increase of approximately US $90,000 per annum.
Conclusion: Introduction of SEDs results in an impressive fall in NSI with minimal cost outlay. (Am J Infect Control 2008;36:180-6.)

Hollow-bore percutaneous needlestick injuries (NSI) remain an important occupational hazard to health care workers (HCW), despite widespread recognition of their ability to transmit bloodborne viruses, in particular, hepatitis B, hepatitis C, and HIV.[1-3] Numerous approaches to reduce NSI have been reported[4-7] but often with limited success, particularly in relation to high-risk hollow-bore injuries. In the United States, this concern was recognized by a landmark passage of federal legislation in the Needlestick Safety and Prevention Act (2000),[8] which requires all health care facilities to provide safety-engineered devices (SEDs) to reduce risk of bloodborne virus acquisition by staff.

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In 2002, we published our experience of NSI[9] over the previous decade in the 800-bed university teaching Princess Alexandra Hospital, Brisbane, Australia, which provides approximately 28,000 bed-days of care per annum. Despite an intensive education program commencing in the early 1980s, the introduction of safer disposal methods as well as an efficient reporting and follow-up strategy capturing over 80% of all NSI, the overall NSI rate in the Hospital in 1999 did not differ significantly from that of 1990. We concluded that engineering, not education, would provide a more effective solution and postulated that the introduction of retractable safety syringes and that the elimination of winged steel butterfly needles would significantly reduce high-risk hollow-bore NSI by 70% and the overall NSI rate by 50%. This paper reports the results of an intervention using engineered devices.

METHODS

Provision of safety syringes

Tenders were called for the provision over a 2-year period of safety syringes for 1 (tuberculin and insulin)-, 3-, 5- and 10-mL syringes with an appropriate range of needle gauges. The critical specification was that normal injection technique must be maintained when using the syringes in that ''the needle must automatically retract when the plunger is depressed fully

into the base of the barrel of the syringe.'' VanishPoint (Retractable Technologies INC, Little Elm, TX) syringes met all tender specifications and were used throughout the trial. The manufacturer attached a variety of needle gauges to the syringes. Conventional syringes and needles could not be replaced for all clinical procedures and remained in use for injection of large volume local anesthetic, blood collection where only a needle and syringe could be used, procedures where a very small gauge needle (eg, 30 gauge) was required and for injection of medication into IV fluid bags and burettes. A decision was also made at the commencement of the trial in 2005 not to replace those needles and syringes that were part of commercially prepacked procedural kits. Ten-milliliter syringes were found pretrial to produce an unacceptable ''spray-back'' with needle retraction and were not used, and, where possible, VanishPoint Blood Tube Holders (Retractable Technologies INC) were used for blood specimen collection.

Education program and SED introduction

At the commencement of the intervention in 2005, an extensive education program was undertaken throughout the hospital to explain the potential benefits of retractable syringes. Thereafter, all conventional syringes and needles that were no longer required were physically removed. Similarly, all conventional winged butterfly needles were physically removed, except in the intensive care unit and pharmacy where safety steel winged infusion sets (BD Safety-Lok; Becton Dickinson, Tokyo, Japan) replaced conventional devices in those circumstances in which use of such devices remained necessary.

A survey conducted as part of the initial education program revealed that staff perceived needle-free IV systems to be of much greater importance in protecting from NSI than retractable syringes.[10] As a consequence of these findings, the SmartSite needle-free system (Alaris Clinico, Baesweiler, Germany) was introduced in mid-May 2005 on all peripheral IV lines, while central and peripherally inserted central catheter lines were thereafter accessed through SmartSite Plus (Alaris Medical Systems, Dublin, OH). Safety intravenous cannulae were already used in the radiology and anesthetic departments and in the intensive care unit but were not introduced more widely because intravenous cannulae were not reported as a substantial cause of NSI in the preintervention period.

Data collection and analysis

The same system of reporting of NSI to the Infectious Diseases Department, which has been in place since 1996, was used throughout the study. All data pertaining to this study were collected prospectively.

The simultaneous introduction of safety syringes and safety winged butterfly needles commenced in October 2004. NSI data from October to December 2004 were considered a run-in period and were analyzed within the preintervention data. Data as counts of NSI for 2000 to 2006 were plotted continuously on Shewhart-EWMA Control Charts.[11] Rates of NSI for the 5 years (2000-2004) prior to the study, the average of the previous 5 years, and of the previous year alone (2004) were then compared with each of the 2 years for the SEDs intervention. Rates of NSI sustained by different staff groups were standardized for comparison using an incidence density denominator of 100 full-time equivalent employees (FTE). The number of full-time equivalent employees in each occupational group was calculated by multiplying the total number of staff employed in that group by the total hours worked and dividing this product by the total of number of hours in the standard working week for that group. This calculation takes into account the reduced exposure time of HCWs employed on a part-time basis. Rates were determined for all occupational groups with clinical exposure within the hospital including medical, nursing, hotel services (catering, cleaning, laundry, orderly), and other (allied health, ie, physical, occupational, and speech therapists; radiographers; anesthesia/perfusion technicians). Staff groups whose FTE were not available (eg, ambulance attendants) were not included in analysis of rates per FTE by staff. During the intervention period 2005-2006, an examination of the effect of needle-free IV systems was made to determine the relative contribution of this system and that of retractable syringes to a reduction in NSI. Epi Info version 6.04 (CDC, Atlanta, GA) software was used to calculate rates (per 100 FTE of at-risk staff) with 95% confidence intervals (CI) and χ^2 test for trend.

RESULTS

The project resulted in a significant reduction in all NSI, inducing a fall of 49% (range, 43.1%-55.7%) in hollow-bore NSI compared with the averaged 5-year rate prior to the intervention (Table 1). In the main, this fall was contributed to by the virtual elimination of NSI related to accessing IV lines, from 26 such injuries in 2004 to 5 in 2006, representing an 81% reduction. More importantly, high-risk hollow-bore injuries were also reduced by 57%, from 72 injuries in 2004 to 31 in 2006. Injuries with winged butterfly needles fell by 35% over the 2-year study period.

During the 5 preintervention years, the rates of NSI were similar ($P = .31$), ranging from 3.01 to 3.77 per 100 FTE (Table 2). The rates for 2005 (1.93; 95% CI: 1.48-2.47 per 100 FTE) and 2006 (1.50; 95% CI: 1.11-1.97 per 100 FTE) were significantly ($P = .00004$) lower

Table 1. Total hollow-bore NSI by year and FTE for Princess Alexandra Hospital staff

Year	Total NSI	Total FTE	Total rate	Medical NSI	Medical FTE	Medical rate	Nursing NSI	Nursing FTE	Nursing rate	Hotel services NSI*	Hotel services FTE	Hotel services rate	Other NSI†	Other FTE	Other rate
Preintervention															
2000	124	2887.63	4.29	27	403.63	6.69	87	1369.47	6.35	2	698.8	0.28	3	415.73	0.72
2001	112	2611.81	4.29	19	378.64	5.02	84	1270.4	6.61	4	638.21	0.63	2	324.56	0.62
2002	105	2866.34	3.66	24	361	6.65	73	1406.22	5.19	7	695.86	1.01	0	403.26	0.00
2003	98	2726.36	3.59	29	452.8	6.40	58	1397.97	4.15	8	485.97	1.65	1	389.62	0.26
2004	103	3052.58	3.37	17	498.78	3.41	70	1534.31	4.56	7	521.58	1.34	0	497.91	0.00
Postintervention:															
2005	66	3164.88	2.09	16	515.33	3.10	45	1590.79	2.83	2	532.51	0.38	1	526.25	0.19
2006	61	3340.6	1.8	17	568.05	2.99	31	1664.79	1.86	4	530.86	0.75	2	576.9	0.35
Total		20650.20	3.23	149	3178.23	4.69	277	10233.95	2.71	37	4103.79	0.90	9	3134.23	0.29
χ^2 Trend			39.80			13.85									
P value			<.00001			.0165									

*Hotel services (catering, cleaning, laundry, orderly).
†Other (allied health, ie, physical, occupational, and speech therapists; radiographers; anesthesia/perfusion technicians).

than the average rate of NSI for the 5 preintervention years (3.39; 95% CI: 2.7-4.24 per 100 FTE). When compared with the rate in year 2004, 3.01 (95% CI: 2.44-3.68) prior to the intervention, the rates for 2005 and 2006 remained significantly lower (P = .00009).

However, during the study period no diminution in NSI rates with solid suture needles was demonstrated, with the mean rate of 0.95 (95% CI: 0.63-1.39) per 100 FTE for 2000-2004 being not significantly different (P = .528) from that for 2005 (0.69 per 100 FTE) or 2006 (0.87 per 100 FTE). Similarly, NSI rates with IV cannulae/stylets remained constant throughout the study period, ranging from 0.19 to 0.31 per 100 FTE with a mean rate for this period of 0.25 (95% CI: 0.10-0.52) per 100 FTE. There was no significant (P = .29) difference in the mean rate of NSI with cannulae/stylets to that of 2005 (0.19 per 100 FTE) and 2006 (0.39 per 100 FTE).

The total percutaneous injuries, listed in Table 2, for both the preintervention and the intervention periods are illustrated using the exponentially weighted moving average (EWMA) statistic (Fig 1). With EWMA controlling for the random variation in these injuries (evident by the spiking nature of the thin injuries count line), the thick EWMA line illustrates the decline in injuries commencing after January 2005.

A series of practical obstacles were encountered during the program:

1. Analysis of a random selection of sharps disposal bins on 2 occasions during the study period indicated that virtually all retractable devices were activated prior to disposal; of those that were not activated, the majority contained fluid thought to be local anesthetic.
2. A series of NSI previously unreported in the hospital and associated with diabetic insulin pens occurred, a finding concurrently experienced and reported in France.[12] The bar chart (Fig 2), after controlling for random variation using the EWMA line, illustrates that this source of injury was substantially eliminated by instructing nursing staff to not use a patient's pen but to use a retractable syringe.
3. Confusion in 2 instances between a 1-mL retractable tuberculin syringe and a 1-mL retractable insulin syringe resulted in 2 patients receiving a 10-fold overdose of insulin. Two ''near misses'' were also reported.
4. Commercially prepared prefilled nonsafety syringes, mostly with enoxaparin sodium, contributed to 6 injuries during the study period.

The introduction of the Smartsite needle-free system proved cost neutral, although the introduction of SmartSite Plus devices cost US $40,000 per annum for the trial period. No significant increase in bloodstream infections was detected during the study period. Substitution of a safety engineered butterfly needle engendered an additional annual cost of $4800 per annum. The major financial impact of the program resulted from the introduction of retractable syringes, an overall annual addition to the budget of $46,000.

DISCUSSION

Some reduction in NSI rates was initially achieved in the 1980s with staff education programs,[13-15] particularly targeting the implementation of universal precautions and the avoidance of recapping. However, the introduction of SEDs appeared to offer a global solution, and this approach was subsequently reflected in revisions of the initial OSHA Blood-borne Pathogen Standard[15] and ultimately in the US Federal Needlestick Safety and Prevention Act (2000).[8] The benefits to HCWs of these guidelines and this legislation have been subsequently confirmed in a number of publications demonstrating reductions in NSI using a variety of or

Table 2. Specific device injuries over the study period for Princess Alexandra Hospital staff

	Preintervention period 2000-2004							Preintervention period 2000-2004		Postintervention period 2005-2006			
	2000	2001	2002	2003	2004	χ^2 *P* value among 5 years 2000 to 2004		2000-2004		2005	2006	χ^2 *P* value among average 2000-2004, 2005, 2006	χ^2 *P* value among 2004, 2005, 2006
	N	N	N	N	N			N	Average 2000-2004	N	N		
Specific percutaneous hollow-bore device:													
Butterfly needle	10	8	8	4	11			41		6	5		
Diabetic pen needle	3	3	4	7	2			19		10	3		
Disposable syringe needle	89	83	72	67	72			383	76	39	31		
Venous or arterial cannulae/stylet	7	5	9	7	8			36	7/2828.94	7/3164.88	13/3340.6		
Venous or arterial NSI					0.26				0.25	0.22	0.39		
Rate per FTE* (95% CI)					(0.11-0.52)				(0.1-0.51)	(0.9-0.44)	(0.21-0.66)		
Total NSI/FTE	109/2887.63	99/2611.81	93/2866.34	85/2726.36	93/3052.58			479/14144.72	96/2828.94	62/3164.88	52/3340.60	2.47, .29	2.36, .307
Rate per FTE* (95% CI)	3.77	3.79	3.24	3.12	3.05	4.71, .3184			3.39	1.96	1.56	24.01, .00004	18.54, .00009
(Medical, nursing, allied health and housekeeping)	(3.11-4.53)	(3.09-4.59)	(2.63-3.96)	(2.50-3.84)	(2.44-3.68)				(2.76-4.13)	(1.48-2.47)	(1.11-1.97)		
Nonhollow-bore comparison:													
Suture needles	40	33	24	18	18/3052.58			133/14144.72	27/2828.94	22/3164.88	29/3340.60	1.28, .528	1.77, .412
					0.59				0.95	0.69	0.87		
					(0.35-0.93)				(0.63-1.39)	(0.44-1.05)	(0.58-1.24)		

*100 Fulltime equivalent.

individual SEDs.[16-19] Our study was initially designed to assess the acceptability and effectiveness of retractable safety syringes, but this aim was confounded by an unexpected response by staff, who strongly perceived that our approach to their protection was misguided and that the introduction of a needle-free IV system should be our first priority. We have previously reported this finding in detail,[10] suggesting that this belief is incorrect. Needle-free IV systems are more likely to prevent incidents of lower risk of transmission because of the small volumes of blood usually involved, whereas retractable syringes used for parenteral injections will prevent high-transmission risk injuries where considerable volumes of blood are often implicated. Nevertheless, we did accept that our colleagues' strongly expressed views indicated not only the need for a promotional program to accompany the introduction of any SED to ensure appropriate user technique but, equally importantly, a program to encourage user acceptance. This conclusion is reflected in the initial very gradual reduction in hollow-bore NSI seen during the first half of 2005, indicating slow uptake in acceptance of retractable syringes (Fig 1).

Our study has demonstrated that the introduction of effective SEDs into a major teaching hospital significantly reduces NSI. The constant and unchanging rate of NSI with solid suture needles implies that the reduction in NSI relates neither to the education program associated with the new devices nor to increased reporting rates but to the effect of SEDs themselves. As in other studies,[20-23] we have shown that needle-free IV systems reduce NSI. However, it is the eventual widespread acceptance of retractable syringe technology to most clinical practices in our hospital that has provided a much improved measure of protection to HCWs from higher risk injuries. The type of retractable syringe that we intentionally chose automatically activates with normal injection technique, thereby eliminating the need for conscious involvement by the HCW. We believe this may be an important design feature that assists in circumstances in which concentration of the HCW may wane, such as prolonged hours[24] of work, night work,[25] and in emergency situations,[26] all of which have been associated with a high rate of NSI.

We have, however, identified during our study a series of important limitations to the introduction and effectiveness of existing retractable technology because current retractable syringe design does not allow its application to all potential uses. We had initially intended to introduce a 10-mL retractable syringe on the basis of a locally developed prototype; this invention substantially eliminates ''dead space'' and thus removes the aerosol effect of residual contents—greatest in large volume syringes—that occurs when the needle retracts into the barrel. Unfortunately, these prototypes were

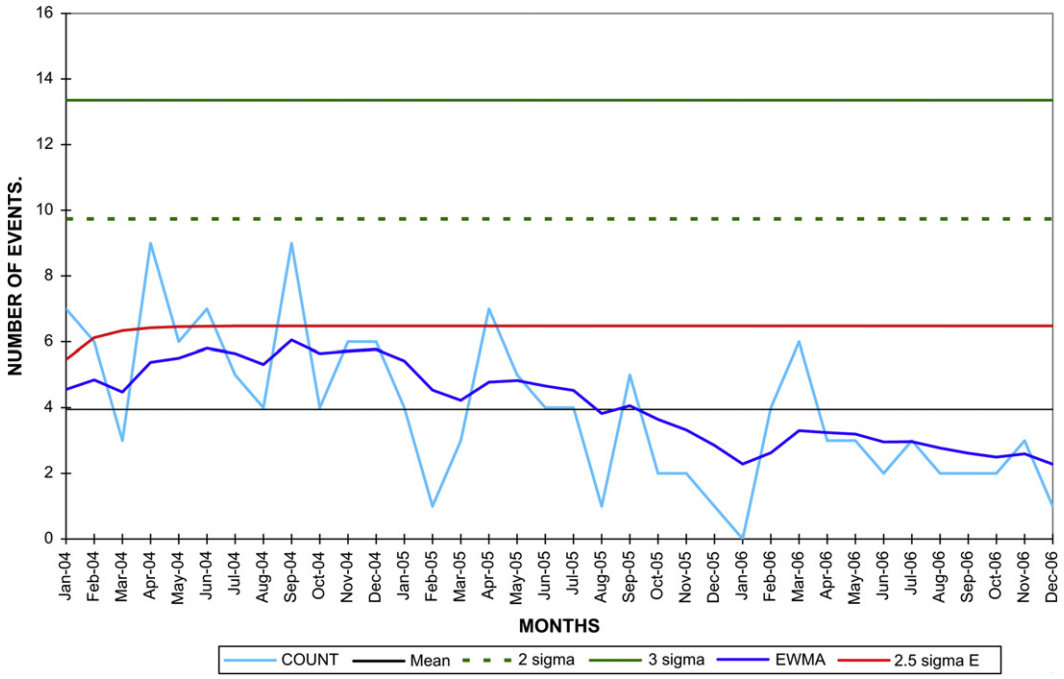

Fig 1. PAH percutaneous hollow-bore injuries January 1, 2004, to December 28, 2006. SHEWHART/EWMA chart exponentially weighted moving average (EWMA) weight 0.2.

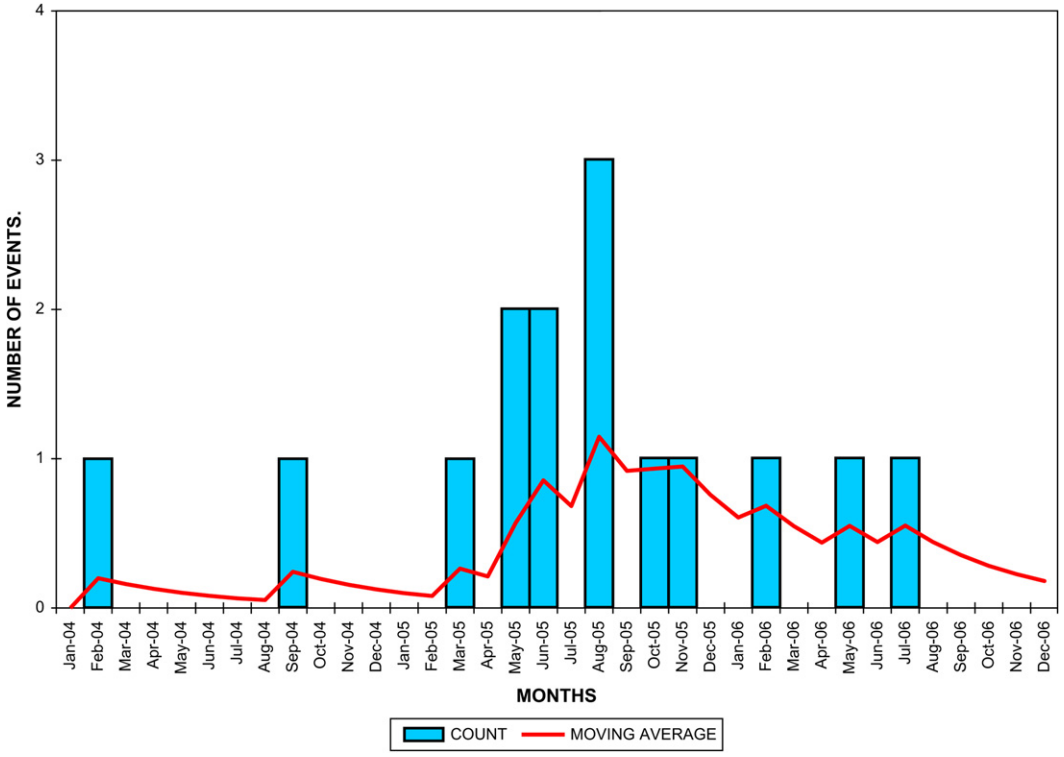

Fig 2. PAH percutaneous injuries—diabetic pens January 1, 2004, to December 28, 2006. Bar chart exponentially weighted moving average (EWMA) weight 0.2.

not available in sufficient quantities for use in our study and current commercially available large volume retractable syringes continue to manifest this constraint. Similarly, in certain clinical situations such as percutaneous administration of local anesthesia, it is not normal practice to inject the entire contents of the syringe; therefore, unless there is a conscious action by the HCW to completely empty the syringe at the end of the procedure, the needle will not retract. We believe that this is the explanation for the small number of ''used but not activated'' syringes that were found during analysis of sharps disposal bins.

The appearance of the VanishPoint 1-mL retractable tuberculin syringe and the VanishPoint 1-mL retractable insulin syringe are similar. However, they can be differentiated because the insulin syringe, in accord with the International Standard, is fitted with an orange needle cap. Nevertheless, confusion between these 2 syringes during our study resulted in 2 patients receiving overdoses of insulin. Until this potential confusion is resolved by manufacturers ensuring that these syringes can be more easily distinguished, we will err on the side of caution and will not recommend use of 1-mL retractable tuberculin syringes in our hospital while we continue to use retractable insulin syringes.

Unlike the United States, Australia has no federal or state/territory legislation mandating the use of SEDs; nevertheless, occupational health and safety legislation is in force and does provide an onus on hospital administrators to provide adequate protection for staff from the risk of NSI. Our study has demonstrated that needle-free IV systems can be introduced without significant financial impediment; however, the major protective benefit against NSI comes from retractable syringes. The overall increased cost in provision of retractable syringes to our 800-bed tertiary teaching hospital was $46,000 per annum, $14.00 for each at risk HCW per year or $2.00 per occupied bed-day per annum. However, the financial impost on the hospital in the future is anticipated to halve, assuming a further reduction in the price of retractable safety syringes with needle attached in Australia in the near future to approximately twice the cost of a conventional syringe and needle. Hospital administrators need to balance this extra cost not only against the time taken to assess staff who sustain NSI and to protect against the fortunately rare acquisition of an occupationally acquired bloodborne virus but, more pragmatically, against the significant anxiety that NSIs are known to induce.[27]

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