Hollow-bore needlestick injuries in a tertiary teaching hospital: epidemiology, education and engineering

R Michael Whitby and Mary-Louise McLaws

ABSTRACT

Objective: To describe the frequency, cause and potential cost of prevention of hollow-bore dirty needlestick injury (NSI) sustained by healthcare workers.

Design and participants: Ten-year prospective surveillance study, 1990–1999, with triennial anonymous questionnaire surveys of nursing staff.

Setting: 800-bed university tertiary referral hospital in Brisbane, Australia.

Main outcome measures: Rates and circumstances of NSI in medical, nursing and non-clinical staff; knowledge of NSI consequences in nurses; and minimum costs of safety devices.

Results: Between 1990 and 1999, there was a significant increase ($P < 0.001$) in the trend of the reported rate of NSI. Of the 1836 "dirty" NSIs reported, most were sustained in nursing (66.2%) and medical (16.8%) staff, with 62.7% sustained before disposal. Hollow-bore injuries from hypodermic needles (83.3%) and winged butterfly needles (9.8%) were over-represented. Knowledge among nursing staff of some of the risks and outcomes of NSI improved over the decade. A trend ($\chi^2 = 9.89$; df = 9; $P = 0.0016$) with increasing rate of reported injuries in this group was detected. The estimated cost of consumables only, associated with the introduction of self-retracting safety syringes with concomitant elimination of butterfly needles, where practicable, would be about $365 000 per year.

Conclusion: More than one NSI occurs for every two days of hospital operation. Introduction of self-retracting safety syringes and elimination of butterfly needles should reduce the current hollow-bore NSI by more than 70% and almost halve the total incidence of NSI.

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THE RECOGNITION in the 1980s of the potential transmission of bloodborne viruses to healthcare workers through needlestick injury (NSI) led to a universal focus on the prevention of such incidents.[1-3] The frequency and nature of injury with dirty hollow-bore needles experienced by healthcare workers in Australian hospital practice were last published almost a decade ago.[1,2] More recently, media concern has turned to the dangers of injuries to members of the public due to discarded needles. Although there is intense lay and political concern over community-acquired NSI, these injuries are uncommon and regarded as lower risk than those sustained by healthcare workers.[4,5]

We describe the rate of reporting and nature of exposure over the past decade from hollow-bore dirty needles in healthcare workers in a tertiary referral hospital. We have also assessed the benefits and consumables cost of widespread introduction of safety devices into the hospital.

METHODS

Princess Alexandra Hospital, Brisbane, is an 800-bed university tertiary referral teaching hospital. Prospective data on staff, self-reported to the infection control service since 1987 as part of the hospital's NSI follow-up protocol, detail percutaneous exposures, including "clean" and "dirty" (ie, injury with a used sharp) NSI and body fluid. Initially, these data were collated and analysed manually, and subsequently with software packages: NOSO 3 (1990–1993),[6] Q Logic (1994–1995)[7] and Epi-Net (1996–1999).[8] Variables within the database for these periods remained essentially unchanged. We excluded body fluid exposures and "clean" NSI, as they pose a low or nil risk, respectively, of bloodborne virus transmission. Staff have been grouped into three classes: clinical (nursing, medical); those at risk of "downstream" injury (housekeeping, catering, wardsmen, Central Sterilizing Supply Department laundry); and other staff (phlebotomists, paramedical, laboratory).

Standardised, anonymous questionnaire surveys in convenience samples of nursing staff were also undertaken throughout the surveillance period at about three-year intervals to determine both the true reporting rate of dirty NSI in this occupational group and their knowledge of potential disease transmission.

Frequencies, rates and proportions were calculated using SPSS for Windows.[9] Epi Info[10] was used to calculate 95% confidence intervals around proportions, χ^2 for trend and Fisher exact tests for significance. Annual rates of NSI were calculated using the number of full-time-equivalent (FTE) positions for each year as denominator. FTEs were provided by the hospital's finance department, and were calculated for

For editorial comment, see page 405

Infection Management Services, Princess Alexandra Hospital, Brisbane, QLD.
R Michael Whitby, FRACP, FRCPA, Director.
School of Public Health and Community Medicine, University of New South Wales, Sydney, NSW.
Mary-Louise McLaws, MPH, PhD, Director, Hospital Infection Epidemiology and Surveillance Unit.
Reprints will not be available from the authors. Correspondence: Dr Michael Whitby, Infection Management Services, Princess Alexandra Hospital, Ipswich Road, Wolloongabba, QLD 4102.
whitbym@health.qld.gov.au

1: Frequency of reported dirty needlestick injury by year of exposure

Year of exposure	Medical staff Number	Medical staff Rate per 100 FTE per annum	Nursing staff Number	Nursing staff Rate per 100 FTE per annum	Downstream staff* number	Other staff* number
1990	13	5.02	95	6.20	12	22
1991	11	3.97	122	7.90	5	8
1992	31	9.64	134	9.15	8	12
1993	27	9.11	98	7.29	10	11
1994	30	10.24	126	10.12	11	18
1995	24	8.27	123	9.54	8	16
1996	34	11.84	139	10.43	9	34
1997	37	12.17	132	9.90	6	42
1998	49	15.08	118	8.70	6	37
1999	53	14.95	128	9.23	9	28
Total	309	10.27	1215	8.79	84	228

Medical staff test for slope $\chi^2=27.68$; df=9; $P<0.001$. Nursing staff test for slope $\chi^2=9.89$; df=9; $P=0.0016$. *Denominator data for all surveillance years not available.

each staff category as the mean of the number of FTE positions at the end of each financial year of the study period. We assumed that significant fluctuations in the number of FTEs due to annual leave or changes in staffing levels did not occur.

RESULTS

Epidemiology

In the 10-year surveillance period, 1836 reported NSI events were classified as "dirty" (Box 1). The reported rate of dirty NSI increased significantly ($P < 0.001$) over the surveillance period, with 66.2% occurring in nurses, and 16.8% in doctors.

The causal device was recorded in 1478 medical and nursing incidents. Injuries not implicating a hollow-bore needle occurred on 513 (34.7%) occasions; of these, the two major contributors were solid suture needles (158/513; 30.8%) and scalpel blades (68/513; 13.3%). The remainder (965/1478; 65.3%) involved hollow-bore needles.

These 965 hollow-bore NSI included injuries due to intravenous cannulas (47; 4.9%), butterfly needles (95; 9.8%) and hypodermic needles (804; 83.3%). Clinical activities associated with NSI involving hollow-bore needles included intramuscular or subcutaneous injections (201; 20.8%), direct IV injections (185; 19.2%), obtaining venous or arterial blood (133; 13.8%), aspirating or injecting into an IV line (82; 8.5%), and other, unspecified activities (345; 35.8%). Of the injuries involving hollow-bore needles, 287 (29.7%) occurred during use, 320 (33.2%) after use but before disposal, 89 (9.2%) during disposal, and 250 (25.9%) during other or unknown circumstances. Recapping of hollow-bore needles caused 134 injuries, with NSI being 3.44 times more likely ($P < 0.001$) to be associated with recapping in the first five years of the surveillance period compared with the latter five years.

Of the injuries sustained by all categories of staff, most (62/104; 60%) of the incidents involving butterfly needles occurred after use, but before or during disposal. Of the IV cannula incidents sustained by all staff, 24/56 (43%) occurred in areas of high dependence: 15 in the emergency department and nine in the operating theatres or intensive care unit. No difference was found in the frequency of IV cannula injuries by hospital location over the 10-year period ($P = 0.694$).

Circumstances associated with NSI in all staff for the entire survey period (Box 2) illustrate that, although downstream injury (ie, injury after disposal in non-clinical staff) contributed to relatively few incidents (11%), more of these were associated with injury during cleaning, reflecting equipment design, than with careless disposal. Only seven injuries were recorded after appropriate disposal, mainly due to overfilling of containers.

One hundred and twenty-seven (6.9%) staff members were exposed to potential infection through NSI from patients with known bloodborne viruses. Five staff suffered injuries associated with HIV-positive patients. Twenty-three, of whom 19 were immune, were exposed to hepatitis B virus (HBV). The incidence of immunity to HBV of staff reporting an NSI increased significantly (trend $\chi^2 = 7.685$; df = 1; $P = 0.006$), from 60.6% (95% CI, 52.0%–68.7%) in 1990 to 89.4% (95% CI, 84.6%–93.2%) by 1999. Since testing of source for hepatitis C began in 1991, 99 staff members have been exposed. No sero-conversion to HIV, HBV or HCV infection was recorded.

Education

We have previously published data demonstrating an improvement of NSI incidence and reporting in nursing staff in

2: Circumstances associated with dirty needlestick injury

Circumstances	Number	% (95% CI)
During use	678	36.9% (34.7%–39.2%)
After use and before disposal	474	25.8% (23.8%–27.8%)
During disposal	276	15.0% (13.4%–16.8%)
After appropriate disposal	7	0.4% (0.2%–0.8%)
While cleaning sharp equipment	116	6.3% (5.2%–7.5%)
After inappropriate disposal	79	4.3% (3.4%–5.3%)
Other	78	4.2% (3.4%–5.3%)
Unknown	128	7.0% (5.8%–8.2%)
Total	1836	

3: Reporting of NSI in anonymous surveys by nurses

Year	Nurse participants	Nurses who sustained any NSI (clean or dirty)		Dirty NSI in nurses who sustained any NSI (clean or dirty)		Nurses who did not report NSI (clean or dirty)	
		Number	% (95% CI)	Number	% (95% CI)	Number	% (95% CI)
1987	336	188	56% (51%–61%)		NA	120	64% (51%–61%)
1989	333	51	15% (12%–20%)		NA	13	26% (14%–40%)
1992	350	53	15% (12%–19%)		NA	12	4% (1%–13%)
1995	197	37	19% (14%–25%)	28	76% (59%–88%)	5	14% (5%–29%)
1998	193	51	26% (20%–33%)	32	63% (48%–76%)	12	24% (13%–38%)
2001	215	47	22% (17%–28%)	34	72% (57%–84%)	7	15% (6%–28%)
		Slope $\chi^2 = 47.95$; df = 1; $P < 0.001$		Slope $\chi^2 = 0.05$; df = 1; $P = 0.81$		Slope $\chi^2 = 4.1$; df = 1; $P = 0.04$	

NA = not available

the late 1980s.[11] Regular anonymous surveys from 1987 onwards (Box 3) demonstrated a highly significant ($P < 0.001$) initial decline in the number of nursing staff who reported sustaining an NSI, although the rate from 1989 onwards has been constant. Similarly, over the period, failure of nursing staff to report NSI significantly fell ($P = 0.0015$) to a low of 4% in 1992, followed by a constant rate of under-reporting of 14%–24% as the decade progressed.

Responses to the knowledge questionnaire indicated an increasingly held view ($\chi^2 = 50.45$; df = 4; $P < 0.001$) that HBV and HIV ($\chi^2 = 28.54$; df = 4; $P = 0.001$) are transmitted by NSI but are not fatal diseases. However, the incorrect perception that HCV is a terminal illness increased from 16.8% (95% CI, 11.8%–22.7%) in 1995 (when it was added to the questionnaire) to 25.1% (95% CI, 19.5%–31.5%) in 2001.

Engineering

Protective IV equipment can be classified by the likelihood of transmission of a bloodborne virus from the NSI it is designed to prevent (Box 4). Although needleless IV systems have been widely implemented, price remains a major barrier to introducing other devices. In general, protective designs are sold at a premium compared with "non-safety" alternatives. Based on our hospital in 2000, the cost of consumables for the device and the likely reduction in NSI associated with hospital-wide introduction of these safety devices is illustrated in Box 4. This calculation assumes that, where a device is introduced, it will prevent all the NSI associated with non-protective equipment. Categories are not mutually exclusive (eg, NSI from aspiration from the side-arm of an intravenous line will be eliminated by introduction of a needleless IV system, but also potentially reduced if the syringe used in the procedure incorporates a self-retracting needle).

DISCUSSION

The only similar Australian study published reported a rate of 9.4/100 FTE per year in nursing staff,[1] similar to our hospital's mean rate of 8.79/100 FTE per year in nursing staff over the 10-year survey period (1990–1999). Only one overseas study[12] is comparable, as it too followed NSI rates in a single institute after multifocused interventions. The researchers assessed NSI rates per FTE per year over an eight-year period (1990–1998).[12] Hollow-bore NSI in all healthcare workers, excluding physicians (who were not assessed), declined from 65/100 FTE per year to 16/100 FTE per year. However, even this improved rate of 16/100 FTE per year is more than twofold higher than that reported previously in Australia[1] and in our study.

Although non-hollow-bore sharps injuries constitute a significant proportion of incidents (34.7%), interventions to prevent NSI have focused on hollow-bore needles, which were the most frequent source of NSI and pose the greatest risk of bloodborne virus transmission.[13] Orientation and reinforcement education sessions were conducted over the entire survey period. Additionally, awareness and "ownership" were facilitated by competitions held to develop educational posters that were subsequently displayed in all clinical areas. Physical interventions included introduction of a recapping device[11,14] (1987) to allow safe recap-

4: Cost–benefit analysis of safety devices

Device	NSI risk avoided	Unit cost of standard design (cents)	Unit cost of safety design (cents)	Anticipated number used per year	Increased budgetary cost per year ($A)	Maximum hollow-bore NSI prevented per year
Syringes with self-retracting needles	High	12	65–110	685 000	365 000–671 000	62.3%
Safety butterfly needles	High	34	127	24 000	22 000	9.8%
Safety intravenous peripheral cannulas	High	86	192	65 000	69 000	4.9%
Needleless intravenous system	Low	NA	NA	NA	22 500*	8.5%

*Based on data supplied by Becton-Dickinson, North Ryde, Sydney, NSW.

ping as an alternative to immediate disposal; positioning of approved "sharps" bins in areas of clinical activity and on trolleys wheeled to the bedside to facilitate immediate needle disposal[15,16] (1989); and introduction of a commercial closed disposal system with sealed containers removed from the hospital by contractors (1989). Safety intravenous cannulas were introduced into the emergency department and operating theatre suite in 1994, but not more widely. The hospital has not used a needleless intravenous (IV) system during the past 15 years, except in the operating theatres from 1995 onwards.

Certain areas of improvement have been identified, including reduction in recapping[11] and increasing knowledge in nurses of the possible outcome of bloodborne virus infection. However, the NSI rate per year at Princess Alexandra Hospital (PAH) has not declined over the past decade. The overall increase in the total reported rate may be artificial. It might be explained by better reporting of NSI by medical staff (Box 1), whose rate of NSI as an occupational group now exceeds that of nurses. In contrast, repeated anonymous surveys of nurses suggest that their rate of reporting dramatically improved to the early 1990s. Since then, a constant 76%–96% of the true rate has been maintained for the rest of the decade (Box 3).

The reduction in hazard achieved from better equipment design is pivotal to improvement in safety and quality in all areas of healthcare facilities.[17,18] While our study has demonstrated an increased knowledge and awareness of the consequences of NSI in nurses, a high endemic level of NSI continues (Box 1). Further improvement in NSI safety is likely to come not from low cost educational programs, but from engineering.[19] The benefits of safer devices over behaviour modification have been widely debated,[17,20] and culminated in 1999 in the United States with the passage of the Needlestick Injury Safety and Prevention Act 2000.[21] This requires the bloodborne virus exposure control plans of US hospitals to "reflect changes in technology that eliminate or reduce the exposure to blood borne pathogens". Multiple safety devices have been developed and variable effects reported.[22-26] All the devices are more expensive than those they replace, and thus their widespread introduction carries significant economic cost. The benefits and limitations of such interventions need careful assessment against the background epidemiology of percutaneous exposures within a given healthcare setting.

Our study indicates that 127 (6.9%) of reported dirty NSI at PAH over a decade were associated with a risk of bloodborne virus acquisition. No seroconversion was detected, but, with the low risk of transmission associated with a single exposure,[27] this outcome was not unexpected. Most healthcare workers are particularly concerned about exposure to HIV. However, while dependent on the background carriage rate of bloodborne virus in a facility's patient population, our experience indicates that Australian healthcare workers are at greatest risk of HCV infection, a disease for which no proven effective prophylaxis exists.

Our data suggest that the introduction of syringes with self-retracting needles could reduce high-risk NSI in our hospital by up to 62%. These devices incorporate automatic retraction of the needle into the barrel of the syringe, provided the user depresses the plunger to the end of the barrel. As this is the normal action when expelling the contents of a syringe, regardless of purpose, it is likely to be carried out without conscious intent. Butterfly needles have again been associated with significant risk of NSI to healthcare workers.[2,28] While protective shielded butterfly needles have been shown to reduce NSI in one trial,[29] they require conscious manipulation of a sheath over the needle at the end of a procedure. There is a need for constant educational reinforcement when using these devices,[29] and this does not augur well for their long term effectiveness in routine clinical practice. Replacement of non-shielded butterfly needles, where practicable, with self-retracting syringes could further reduce NSI by up to 10%.

The crude estimated extra cost per year at Princess Alexandra Hospital for syringes with self-retracting needles at $0.65 per unit is $365 000. This figure is conservative, not taking into account indirect savings from reduction in loss of staff time associated with NSI assessment and follow-up, decreased consumables for laboratory testing of staff and patients, and the intangible benefits of reduced staff anxiety.[30] Our estimate is not intended to represent a formal cost–benefit analysis, but simply the likely funding necessary to implement purchase of consumables.

Our data show that, at one tertiary referral hospital, more than one potentially high-risk NSI occurs for every two days of hospital operation. Hospital administrators have been shown to be tolerant of a finite NSI rate, although the acceptable threshold varies with their awareness and knowledge of the issue.[31] It is they who must determine whether the budgetary implications of protective devices are justified by the potential reduction in these exposures. This is not the case in the US, where legislation was introduced without consideration of either its financial impact on individual healthcare facilities, or the differing impacts of varying safety devices on reduction of high-risk exposure. Such a situation should not be allowed to occur in Australia. Introduction of safety devices should not simply be an emotional response to heathcare worker concerns, but must be shown to have proven efficacy and must be accompanied by a cost-containment strategy. Only well-designed clinical trials can provide these data.

COMPETING INTERESTS

None identified.

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book review

Accessible information on liver disease

Hepatitis C, other liver disorders and liver health. A practical guide. Geoffrey C Farrell. Sydney: MacLennan and Petty, 2002 ($71.50, xi + 324 pp). ISBN 0 86433 157 6.

AS THIS BOOK claims to be aimed at general practitioners and "a broader readership", including laypeople, I felt that, as a specialist hepatologist, I was not necessarily the best person to review it. I asked a layperson and an experienced general practitioner for their opinions.

From the layperson: The book is clearly written and the language and concepts are accessible to a non-medical reader. I particularly liked the style of writing and the tone, which was non-dogmatic when discussing alternative therapies, yet able to convey warnings when necessary. Geoffrey Farrell also shows cultural awareness. The book is easily followed as a reference text. If I had liver disease, I would want to have this book.

Colleen Vaughan
Secondary School English teacher, Essendon, VIC

From the general practitioner: The book is comprehensive and informative. It will answer all your questions — if you can find what you are looking for. Finding information was a problem, as there is so much information packed into the 320 pages. For example, in the chapter "Diet and liver disease — is there a liver cleansing diet?" I had to wade through three recipes, four tables and 18 pages to find the answer — no! I also thought that starting each chapter with case studies, but not presenting the commentaries until the chapter's end, was confusing. I would have preferred much of the information found in tables and charts to have been placed in appendices so that the book flowed more smoothly.

Robert Benson
General Practitioner, Footscray, VIC

From the specialist: Does this book add to the cornucopia of print and electronic resources on hepatitis C? Yes, it does! For the health care worker it gives a sensitive, yet scientific, approach to issues which often deeply concern our patients, but are sometimes trivialised by health professionals (eg, diet, complementary therapies). Geoffrey Farrell is courageous enough to debunk the so-called "liver cleansing diet", even if it did take him 18 pages (see above). On the other hand, the book gives the layperson information on hepatitis C and other liver disorders which is otherwise difficult to access. The style is idiosyncratic and may not appeal to all, but overall it has achieved its goal. It is trustworthy and novel and I'll be recommending the book both to patients and health professionals.

Katrina J R Watson
Hepatologist, Fitzroy, VIC