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ORIGINAL ARTICLE

Costs of needlestick injuries and subsequent hepatitis and HIV infection

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ABSTRACT

Background: Physicians, nurses and other healthcare workers (HCWs) are at risk of bloodborne pathogens infection from needlestick injuries, but costs of needlesticks are little studied.

Methods: We used the cost-of-illness and incidence approaches. We used the perspective of the medical provider (medical costs) and the individual (lost productivity). Data on needlesticks, infections from hepatitis B and C (HBV, HCV) and human immune-deficiency (HIV) among HCWs, as well as data on per-unit costs were culled from research literature, Centers for Disease Control and Prevention reports, and Bureau of Labor Statistics reports. We also generated estimates based upon industry employment and scenarios for source-patients. These data and estimates were combined with assumptions to produce a model that generated base-case estimates as well as one-way and multi-way probabilistic sensitivity analyses. Future costs were discounted by 3%.

Results: We estimated 644 963 needlesticks in the healthcare industry for 2004 of which 49% generated costs. Medical costs were $107.3 million of which 96% resulted from testing and prophylaxis and 4% from treating long-term infections (34 persons with chronic HBV, 143 with chronic HCV, and 1 with HIV). Lost-work productivity generated $81.2 million, for which 59% involved testing and prophylaxis and 41% involved long-term infections. Combined medical and work productivity costs summed to $188.5 million. Multi-way sensitivity analysis suggested a range on combined costs from $100.7 million to $405.9 million.

Conclusion: Detailed methodology was developed to estimate costs of needlesticks and subsequent infections for hospital-based and non-hospital-based health care workers. The combined medical and lost productivity costs comprised roughly 0.1% of all occupational injury and illness costs for all jobs in the economy. We did not account for lost home production or pain and suffering costs, however, nor did we estimate benefit/cost ratios of specific interventions to reduce needlesticks.

Introduction

Physicians and nurses frequently voice fear regarding needlestick injuries (NIs) and possible subsequent infections[1,2]. The most widely cited study attempting to estimate the national number of annual needlesticks (384 325) is limited to hospitals[3]. Hospitals, however, accounted for only 40.1% of employment within the healthcare sector in 2004[4]. The most thorough published literature review includes ranges for per-person costs of needlesticks, but our literature search found only one estimate of national total costs[5,6]. The national estimate by Lee *et al.*[6] assesses immediate testing and related costs but gives less attention to long-term costs of treatment of subsequent infections. In our study, we estimate costs of needlesticks and subsequent infections from hepatitis B and C (HBV, HCV), and human immune-deficiency (HIV) among all healthcare workers (HCWs), including non-hospital-based workers, for 2004. Information on costs is important since costs now inform many medical decisions by employers, governments, insurance firms, unions, and individuals.

Methods

Our analysis involved four parts: (1) estimation of incidences of needlesticks and subsequent infections, (2) estimation of per-person medical and lost-work productivity costs, (3) multiplication of incidences with per-person costs, and (4) sensitivity analyses. We used the perspective of the medical provider (medical costs) and the individual (lost wages). We used the incidence method and calculated current and future lifetime costs associated with needlesticks occurring in 2004 to persons aged 40 and until their death.

We defined HCW as anyone employed in the health services industry as defined by the Bureau of Labor Statistics (BLS). BLS categories for the health services industry include: public and private hospitals, nursing and residential care facilities, offices of physicians, dentists, and other practitioners, outpatient centers, other ambulatory services, and medical laboratories.

Our definition of HCWs based on industry is consistent with the focus on hospitals only in Panlilio *et al.*[3] and inside and outside hospitals in Shah *et al.*[7] Panlilio *et al.*[3] estimate 384 325 reported and unreported needlesticks for hospital-based HCWs. We estimated the number of needlesticks outside hospitals with two factors: (1) percentage of employment within and outside hospitals, and (2) relative risks of HCWs within and outside hospitals. We needed only the percentage of HCWs inside hospitals, not the actual number. In 2004, hospital employment was 5 220 520 and total healthcare (health services) industry employment was 13 012 240. Hospital employment therefore represented 40.1% (5 220 520/13 012 240) and non-hospital employment represented 59.9% of total employment in the healthcare sector.

We estimated relative risks with data from the literature. Shah *et al.*[7] provide the only estimate with which we are aware of needlestick incidence both inside and outside hospitals. Shah *et al.*[7] estimate needlesticks incidence of 71.3 per 10 000 full-time-equivalent workers outside hospitals and 156.9 for workers inside hospitals. The ratio (71.3/156.9) yields 45.4% risk for non-hospital-based compared to hospital-based workers. (We did not directly estimate our needlesticks with the Shah *et al.*[7] incidence rates since they used only workers' compensation data from only one state – Washington. Their data are nevertheless internally consistent so that ratios are reliable for our purposes.) Combining the Panlilio *et al.*[3], BLS, and Shah *et al.*[7] estimates, we generated our own base-case estimate of number of needlesticks outside hospitals: 384 325 (59.9%/40.1%) × 45.4% = 260 638. Our estimate of all needlesticks in the healthcare sector was therefore 384 325 + 260 638 = 644 963.

Following Panlilio *et al.*[3], we assumed 43.4% of needlesticks were reported. Allowing for the fact that some unreported needlesticks would nevertheless be tested (perhaps privately), we estimated 316 419 needlesticks involved testing. We assumed the 328 544 needlesticks not tested did not generate any testing costs but may have generated subsequent infection costs implicitly captured in our estimates of infection costs below.

We applied estimated percentages, ratios from the literature, and clinical judgment to generate estimates of needlesticks originating in 2004 into categories depending on whether source-patients were tested and whether source-patients or HCWs became infected. Following Sepkowitz and Eisenberg[8], we assumed the numbers of potential infections among HCWs matched the prevalence of infection in the US population: 1.25 million for HBV, 3.9 million for HCV (2.7 million chronic), and 1.11 million for HIV (CDC Fact Sheets). We assumed minimal testing for 60–98% of needlesticks and substantial testing for 2–40% of needlesticks. 'Minimal' meant one simple blood test each for source-patient and HCW. 'Substantial' added prophylaxis for the HCW.

To estimate medical costs-per-needlestick prior to treatment for infection we first calculated a mean from eight studies (six from a published literature review[5] and one each from WC Lee *et al.*[6] and Shah *et al.*[7]) and second, combined the mean with information on source-patients from Orenstein *et al.*[9] to generate six separate estimates. We used cost data from Orenstein *et al.*[9] since it was the most widely cited of all cost studies in the JM Lee *et al.*[5] review and since it has the most detail on cost-per-disease and source-patient. Of all studies we considered, these eight were the most recent and contained information on costs that excluded subsequent infections. All amounts were inflated to reflect 2004 dollars. The inflation factor was the ratio of the US 2004 number from the US Consumer Price Index (Medical Care All Urban Consumers)[10] divided by the index number for the relevant year in the study we updated. For example, the relevant year for JM Lee *et al.*[5] was 2002 and our factor was 310.1/285.6. The lowest estimate ($154) corresponded to medical costs for a low-risk source-patient who tested negative for all infections and for which the HCW sought no further testing. A high estimate ($864) was for high-risk source-patient testing, HCW testing, and HCW prophylaxis for possible transmission of HBV. Medical costs-per-needlestick for high-risk source-patients for testing and prophylaxis for HIV was drawn from the most recent and careful study involving HIV ($2257 and $2411)[11].

To estimate subsequent infections, we used national estimates of incidence of HBV, HCV, and HIV for all HCWs[9,12,13]. For example: (1) CDC estimates 385 new HBV infections among HCWs within hospitals in 2001 (MJ Alter e-mail 11/29/05), (2) Sepkowitz and Eisenberg[8] estimate 50–150 HCWs within hospitals become infected with HCV per year, (3) Do *et al.*[12] report only three cases of HIV transmission to HCWs from 1996 to 2001. We assumed only chronic, not acute, HBV- and HCV-generated medical costs, but both chronic and acute generated lost productivity. We assumed all HIV generated medical costs. Applying assumptions from the literature, we developed estimates for incidence of job-related infections originating in 2004 (Table 1 footnotes). Costs assumptions relied on: Marshall *et al.*[13] and Salomon *et al.*[14] for lifetime costs of HBV and HCV, and Schackman *et al.*[15] for lifetime costs of HIV. Finally, we assumed a 3% discount rate and adjusted for inflation to 2004 dollars.

For lost productivity, we first constructed a weighted average hourly wage ($32.71) based upon percent contribution to needlesticks experienced by nine major occupations in Shah *et al.*[7]: physician, nurse, laboratory technician, technologist, housekeeper, nursing aide, surgery attendant, dental assistant, and dentist. These nine were selected because they were easily matched to Bureau of Labor Statistics (BLS) data on wages. The weighted-average wage was higher than the registered nurse wage ($26.71)[4].

Second, we assumed wage inflation of 3% per year, productivity growth of 1% per year, and discount rate, 3%. These assumptions implied that real, discounted future wages grew 1% per year.

Third, we made assumptions for hours of work-loss. In the simplest case, we assumed 1 hour lost by the exposed HCW when the low-risk source-patient was tested and found free of infection. If the exposure was complex, involving multiple tests and prophylaxis, we assumed more work-loss. We assumed HIV tests and prophylaxis would result in more work-loss than HBV or HCV. We assumed HCWs who became infected generated the most work-loss and 50% (hepatitis) and 100% (HIV) survived past retirement at age 65, whereas 50% (hepatitis) died before retirement, losing years of work. Our assumptions about lost work productivity may also be interpreted as lost work 'presenteeism,' i.e. lost production for HCWs physically, but not mentally, at the job[16]. Lee *et al.*[6] report 79% of work-loss due to 'emotional distress and anxiety.' Our clinical judgment was that even for low-risk needlesticks, some reduced 'presenteeism' was likely.

Fourth, based on the Gillen *et al.*[17] findings that typical HCWs with needlesticks were female nurses, average age 38, we assumed the base-case was a 40-year-old female registered nurse with average life expectancy of 25 years following initial HBV or HCV or HIV infection.

Fifth, we assumed the economy operated at full employment so lost wages represented lost production.

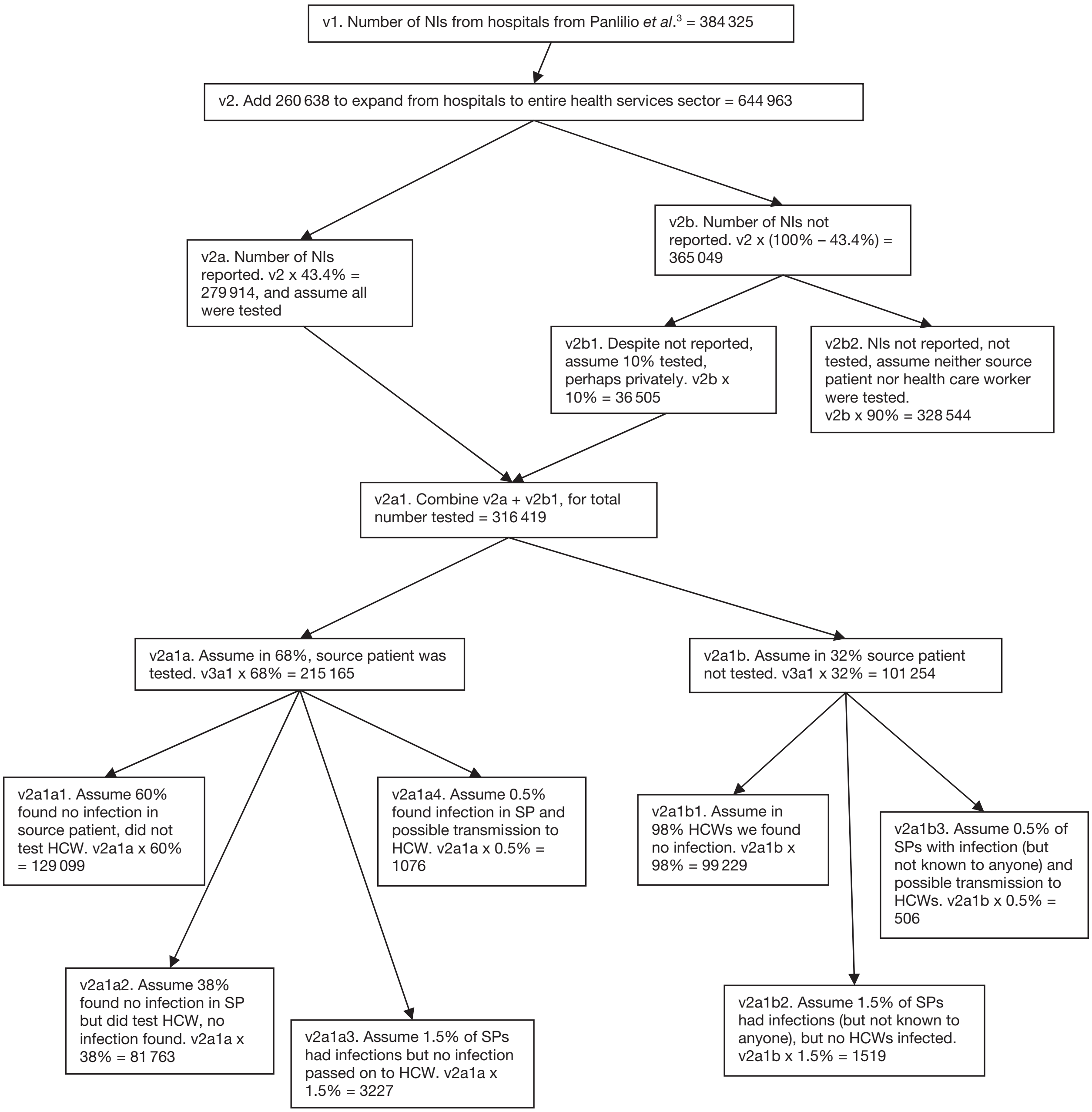
We conducted three sensitivity analyses: one-way ± 15%, one-way 14 case-studies, and multi-way Monte Carlo simulation. The one-way ± 15% analysis provided a useful picture of which variables were most influential from a mathematical point-of-view. The one-way case-study analysis provided an understanding of influential variables based upon what the literature suggests how values of these variables might differ. The multi-way Monte Carlo analysis provided an understanding of how simultaneous differences in variable values based on the literature might generate alternative estimates of combined costs.

For the multi-way Monte Carlo sensitivity analysis, we assumed eight discrete probability distributions corresponding to the eight variables in the one-way case-study analysis and, in turn, associated with 28 values. The eight variables included: medical costs of needlesticks prior to known infection; three different medical costs for treatment of HBV, HCV, and HIV; lost wages for needlesticks prior to known infection; and three different lost wages amounts for HCWs with infections from HBV, HCV, or HIV. For example, we assumed five values and probabilities for medical costs of needlesticks prior to known infection (probability = 1/5 for each of these five values: $56 616 035, $83 531 854, $103 125 746, $124 472 775, $227 443 833), and three values and probabilities for medical costs for treatment of HBV (1/3 apiece for each of these three values: $209 791, $924 188, $1 968 520). The

28 values included eight from our base-case and 20 from the literature based upon values in the one-way case-study sensitivity analysis (Table 5). The Monte Carlo technique took 10 000 random draws and each draw was the sum of one value each from eight variables corresponding to eight probability distributions.

Results

Figure 1 presents base-case estimates for needlestick incidence. Whereas 644 963 needlesticks were estimated, only 316 419 (49%) received testing. Of these 316 419, we assumed 68% involved testing the source-patient and 32% involved testing only the



Assumptions for variables, '*v*':

v2a and v2b. 43.4% reporting from Panlilio *et al.*[3]

v2a1 and v2b2. 10% and 90% were professional judgment of the bloodborne pathogens surveillance nurse

v2a1a and v2a1b. 68% and 32% estimated by assuming 95% of source patients in hospitals were tested and 30% of source patients outside hospitals were tested: ((384 325 × 95%) + (260 638 × 30%))/644 963 ≈ 68%. The 95% and 30% were the professional judgment of the bloodborne pathogens surveillance nurse

v2a1a1, v2a1a2, v2a1a3, v2a1a4, v2a1b1, v2a1b2, v2a1b3. 98%, 60%, 38%, 1.5%, 0.5% were professional judgment. Notice 1.5% + 0.5% = 2% which is the approximate percent of population with either HBV or HCV or HIV. From CDC 'Fact Sheets': 1.25 million with HBV; 3.9 million with HCV (2.7 with chronic HCV); 1.11 million with HIV. U.S. population was 293.9 million in 2004. Sum of infections is 6.26 and divided by population is roughly 2%

v2a1a4 and v2a1b3. Note words 'possible transmission' which are different from 'no infection' in v2a1a3. Actual infections in Tables 3 and 4 were less than 'possible transmissions'

Figure 1. *Flow chart for needlestick injuries (NI)*

HCW. Because roughly only 2% of source-patients were likely infected and because even if infected, there was only a small chance viruses would be transmitted, we estimated only 1582 (0.2%) of needlesticks involved possible transmission (add variables v2a1a4 + v2a1b3 = 1582).

Table 1 combines information on number of cases (Figure 1), with information on testing cost-per-case into three categories. Within category 1 were 129 099 needlesticks for which the source-patient was found free of infection. This 129 099 was multiplied by our minimal per-case amount of $154 to yield $19.9 million. Category 2 was divided into subgroups depending on complications of 86 069 needlesticks for which both source-patient and HCW were tested. Within category 2, substantial testing and some prophylaxis was administered for 861 needlesticks involving possible HBV, 2670 for HCV, and 775 for HIV. The 101 254 needlesticks involving only HCW (not source-patient testing) in category 3, were similarly divided. The greatest dollar ($51.7 million) subgroup in Table 1 was generated by 99 229 needlesticks receiving moderate

Table 1. *Number and medical cost of needlesticks testing within source-patient and disease categories*[1]

1. Test source-patient only, find no infection (v2a1a1 = 129 099) × (per person cost for source-patient test)
   = 129 099 × $154[2]
   = $19 881 246
2. Test source-patient and HCW, including those infected (v2a1a2 + v2a1a3 + v2a1a4)) = 81 763 + 3227 + 1079 = 86 069
   Minimal testing: v2a1a2 × ($154 + $154)[3] = 81 763 × $308 = $25 183 004
   Substantial testing: v2a1a3 + v2a1a4: 3227 + 1079 = 4306[4]
      HBV test and prophylaxis: 861 × $852[5] = $733 572
      HCV test and prophylaxis: 2670 × $726[6] = $1 938 420
      HIV test and prophylaxis: 775 × $2411[7] = $1 868 525
   Total: $29 723 521
3. Test HCW only, not SP, including those infected (v2a1b1 + v2a1b2 + v2a1b3 = 101 254)
   Moderate testing: v2a1b1 = 99 229 × $521[8] = $51 698 309
   Substantial testing: v2a1b2 + v2a1b3 = 1519 + 506 = 2025[9]
      HBV test and prophylaxis: 405 × $698[10] = $282 690
      HCV test and prophylaxis: 1256 × $572[11] = $718 432
      HIV test and prophylaxis: 364 × $2257[12] = $821 548
   Total: $53 520 979
4. Total: $19 881 246   per *tested* needlestick cost is $104 661 090/316 419 = $326
   + $29 723 521
   + $53 520 979
   $103 125 746

1. The authors averaged estimates for eight studies for our base-case cost of needlesticks prior to infection. Six were from JM Lee[5] and one each from WC Lee[6] and Shah *et al.*[7]. The six studies from JM Lee were Dale ($662 2002), Friedland ($739), Orenstein ($391), Llewelyn (average of $299 and $309 equals $304), Sellick ($119), and Jagger ($834). WC Lee's average cost per needlestick per injured nu rse is $259 in 2004 dollars. WC Lee estimate only 44% of $259 or $114 is due to direct medical costs. We used the per-NI-per-nurse rather than per-NI (which is smaller) since ultimately we multiply by the number of HCWs who reported or sustained an NI. Backcasting from 2004 to 2002 yields (285.6/310.1) × $114 = $105

   Shah *et al.*[7] reports 2536 workers compensation claims outside hospitals (with average medical cost of $311) and 767 inside hospitals (average medical cost of $324). The weighted average for costs is $314. Given Shah *et al.*[7] information on claims with work-loss and claims with seroconversions we judged that the $314 largely reflects medical costs of needlesticks before infection. Adjusting $314 for inflation yielded $370 in 2004. Our eight-study mean was adjusted to reflect source-patient status from Orenstein *et al.*[9]
2. The authors' 8-study mean adjustment was 1.128 which when multiplied by $126 yielded $142.1. The $126 was from Orenstein *et al.*[8] with update to 2002 from JM Lee *et al.*[5] Inflation factor was ratio of 2004 to 2002 BLS medical index for all urban consumers: 310.1/285.6 = 1.08578 and 1.08578 × $142.1 = $154
3. The authors assumed $154 for SP and another $154 for HCW
4. In US population, roughly 1.25 million are infected with HBV, 3.9 million with HCV and 1.11 with HIV (CDC Fact Sheets for HBV, HCV, HIV). 1.25 + 3.9 + 1.11 = 6.26. And 1.25/6.26 = 0.20; 3.9/6.26 = 0.62; 1.11/6.26 = 0.18. So, out of total in (v2a1a3 + v2a1a4 = 4306), 20% = 861 for HBV; 62% = 2670 for HCV; 18% = 775 for HIV
5. Orenstein *et al.*'s[9] midpoint for HBV: $504-$385 = $119; $119/2 = $59.5; $385 + $59.5 = $444.5. The $444.5 number is midpoint between Orenstein's $385 to $504. Must adjust for 8-study mean and inflation: $444.5 × 1.128 × 1.08578 = $544. But Orenstein's estimate does not account for testing SP and HCW. Using footnotes 2 and 3 above, we added $154 twice: $544 + $154 + $154 = $864
6. Orenstein *et al.* $341 × inflation factor 1.08578 × our 8-study mean factor 1.128 = $418. Again, the authors must add $154 twice to account for SP and HCW tests. Sum equals $726
7. Orenstein data on HIV are outdated. We used, instead, Holodnick *et al.* (2000)[11]. $1937 × inflation factor 1.08578 = $2103. And adding $154 twice yields $2411
8. Orenstein *et al.*'s[9] $425 × inflation factor 1.08578 × 8-study mean factor 1.128 = $521
9. See footnote #4. 2025 × 20% = 405 with HBV test; 2025 × 62% = 1256 with HCV test; and 2025 × 18% = 364 with HIV test
10. Same as footnote #5 only must subtract $154 since source-patient not tested. $852 – $154 = $698
11. Same as footnote #6 only must subtract $154, since source-patient not tested. $726 – $154 = $572
12. Same as footnote #7 only must subtract $154. So $2411 – $154 = $2257

testing. The total dollar amount was $103.1 million and the average medical testing cost-per-needlestick (not covering subsequent infection) was $326.

Table 2 presents findings and assumptions for base-case estimates for incidence and medical costs of HBV, HCV, and HIV. For example, we estimated 143 new cases of chronic HCV by adjusting estimates from Sepkowitz and Eisenberg[8] to reflect HCWs employed outside hospitals and assuming 85% of new infections became chronic[18]. The total number of HBV, HCV and HIV infections (178) was considerably less than the number of possible transmissions in Figure 1 (1582). The medical costs for 34 (chronic-HBV), 143 (chronic-HCV), and 1 (HIV) infected patients were $924 188, $2 877 160, and $385 200, for an overall medical cost of $4 186 548.

Table 3 presents estimates of lost work productivity for needlesticks before (top panel) and after (bottom panel) subsequent infection. The largest dollar amount, $32 557 034, was in category 3 (testing for HCWs only, not source-patients). The total dollar amount of lost work productivity prior and subsequent to known infection was $81 187 457.

Table 4 combines the estimates from previous tables. In the base-case, total costs were $188 499 751. Approximately 80% were attributed to testing and prophylaxis and 20% to subsequent infection.

Figure 2 presents a one-way sensitivity analysis for ± 15% variation. The variables with the largest influence were the medical costs per needlestick prior to known infection and the number of needlesticks. Variables with the least influence related to HIV.

Table 5 presents a one-way case-study sensitivity analysis with 14 scenarios. Three factors accounted for the widest variation: the number of needlesticks, the medical cost-per-needlestick (not accounting for subsequent infection), and lost-work productivity. These three factors are the first three listed in the lower and upper bound panels.

Figure 3 presents a histogram of the 10 000 random draws from the eight probability distributions of our Monte Carlo simulation. The mean, $217 407 490, was larger than our base-case since several of the literature-based scenarios in our case-study sensitivity analysis had absolute values for higher cost estimates much larger than the absolute values of lower cost estimates. The minimum and maximum values were $100 733 158 and $405 874 742. The standard deviation was $66 500 001. One percent of 10 000 draws fell below $112 106 945 and one percent fell above $395 123 948.

Discussion

We estimated 644 963 needlesticks in the healthcare industry which generated $188.5 million for combined costs, including $107.3 million for medical costs and $81.3 million for lost productivity. These dollar amounts are large. They can be compared to the $100 million medical costs for the 400–500 children who undergo liver transplantation each year[19], and the $300 to $400 million medical costs for cervical cancer[20]. But the costs are below: (1) the medical costs for Parkinson's disease $7.3 billion[21], (2) the costs of other categories of occupational injuries (back sprain, over $1100 million; and fractures, over $300 million) for HCWs[22], and (3) roughly 0.1% of all occupational injury and illness costs ($155 billion in 1992 or roughly $159 billion in 2004 allowing for 34.6% inflation and 32.0% decrease in numbers of injuries)[10,23,24].

A literature search uncovered only one national cost estimate: WC Lee *et al.*[6] estimate $65 million (2004) of which $28.6 million (44%) are medical costs. Our methodology differed substantially from Lee *et al.*[6]. First, Lee *et al.*[6] extrapolated a national estimate based upon a sample of 110 nurses with needlesticks who were caring for only diabetic patients. (Their findings pertaining to the 110 nurses appear robust in our opinion). Moreover, these 110 nurses were drawn from a sample of 400 nurses who were, in turn, drawn from a sample of 5000 nurses who received unsolicited e-mail inquiries in August and September, 2004. Lee *et al.*[6] never claimed that their sample of diabetic-treating nurses was representative of all HCWs. We, on the other hand, attempted to include all HCWs – physicians, nurses treating patients without diabetes, nursing aides, orderlies, housekeepers, laboratory technicians, and so on. Second, the Lee *et al.*[6] extrapolation used the older '600 000–800 000' CDC needlestick estimate[3]. We used the newer CDC estimate from Panlilio *et al.*[3] since it was 'more reliable'[3] and because it used 'data from the two US surveillance systems that collect information on percutaneous injuries…'[3].

Our estimated costs exceeded those in WC Lee *et al.*[6] for many reasons. For example, we included, but they excluded, subsequent infections. But most importantly, we relied on detailed methodology that resulted in an estimate of $326 medical cost-per-needlestick prior to infection whereas their estimated midpoint medical cost is $76. We believe our estimate is more accurate for four reasons. First, the JM Lee *et al.*[5] review supports our higher estimate. Nine of 12 studies (JM Lee *et al.*[5]) produce 29 estimates for medical only (ignoring lost productivity). The two lowest estimates are $55 and $125; the two highest are $2103 and $4089 (all 2004). The WC Lee[6] $76 estimate is next to the bottom of JM Lee's[5] list of 29 estimates. Second, a recent study by Shah *et al.*[7] generates a $406 (2004) estimate for cost-per-needlestick. Third, we estimated a $185 minimum cost for low-risk source-patients free of infection at the University of California-Davis Medical Center in 2006

Table 2. Number and medical costs for cost-generating cases with HBV, HCV, or HIV

Chronic HBV
Base-case number estimate: 34
Base-case assumptions:
1. 385 new infections in HCWs in hospitals
2. 261 new infections in HCWs outside hospitals
3. 70% of occupational exposures due to needlesticks
4. 7.5% became chronic and generated costs

Base-case cost estimate: 34 × $27 182 = $924 188
Base-case assumptions:
1. Per-case estimates from Marshall *et al.*[13] and Salomon *et al.*[14]
2. Inflated from 2001 to 2004
3. 3% discount rate

Chronic HCV
Base-case number estimate: 143
Base-case assumptions:
1. 100 new infections in HCWs in hospitals
2. 68 new infections in HCWs outside hospitals
3. 100% of occupational exposures due to NIs
4. 85% became chronic and generated costs

Base-case cost estimate: 143 × $20 120 = $2 877 160
Base-case assumptions:
1. $17 700 per case from Salomon *et al.*[14]
2. Inflated from 2001 to 2004
3. 3% discount rate

HIV
Base-case number estimate: 1
Base-case assumptions:
1. Our inference from Do *et al.*[12] Only 3 cases over 5 years (1996–2001)

Base-case cost estimate: 1 × $385 200 = $385 200
Base-case assumptions:
1. $385 200 per case from Schackman *et al.*[15]
2. 3% discount rate

Total: $924 188 + $2 877 160 + $385 200 = $4 186 548

HBV: Number
1. 385 is CDC estimate for 2001 in MJ Alter's e-mail to first author, 11/29/05
2. The authors assumed the same ratio of needlesticks outside hospitals to needlesticks inside hospitals in Figure 1 applied: (260 638/384 325) × 385 = 261
3. 70% was professional judgment. Unlike HCV, HBV is frequently transmitted without needlesticks
4. 7.5% was the midpoint in Sepkowitz and Eisenberg's[8] assessment of percent of new HBV infections that become chronic (5% – 10%) We assumed only chronic HBV generated medical costs. The authors therefore assumed 92.5% become acute.
   Base-case number estimate: (385 + 261) × 70% × 7.5% = 34 for chronic and (385 + 261) × 70% × 92.5% = 418 for acute.

HBV: Cost
The authors combined estimates from Marshall *et al.*[13] and Salomon *et al.*[14] to produce a lifetime cost estimate for chronic hepatitis B. The authors believe the lifetime costs for both hepatitis B and C are a little low in Marshall *et al.*[13] compared to the literature in JM Lee *et al.*[5] For example, Wong *et al.*[31] estimated costs of $30 000 to $33 000 in 1995 whereas Marshall *et al.*[13] estimated a cost of $15 079. The authors nevertheless assumed that the *ratio* of costs for HBV to HCV from Marshall *et al.*[13] was reasonable. The ratio is: $15 079/$11 161 or 1.351. The authors preferred the Salomon *et al.*[14] estimates for HCV. Below, the authors assumed a lifetime cost for HCV was $17 700 (2001 dollars) and inflating yields (310.1/272.8) × $17 700 = $20120 (2004 dollars). Multiplying these amounts yielded $20 120 × 1.351 = $27 182

HCV: Number
1. 100 new infections is mid-point in the '50 to 150' estimate from Sepkowitz and Eisenberg[8]
2. The authors assumed the same ratio of needlesticks outside hospitals to needlesticks within hospitals in Figure 1 applied: (260 638/384 325) × 100 = 68
3. The authors' clinical judgment was that virtually all HCV transmissions in HCWs would be due to needlesticks
4. Cotran *et al.*[18] suggest 85% of new HCV become chronic. Therefore, 85% × 168 = 143. And, 15% × 168 = 25 become acute

HCV: Cost
Salomon *et al.*[14] provided four estimates for chronic HCV in 2001: $8200 for no treatment, $10 200 for interferon, $13 300 for pegylated interferon, $17 700 for interferon with ribavarin, and $22 000 for pegylated interferon and ribavarin. The authors selected $17 700 for interferon and ribavarin as most representative of American medical care in 2004. To inflate to 2004, the authors multiplied by (310.1/272.8) × $17 700 = (see HBV cost footnote above) to yield $20 120

HIV: Cost
Schackman *et al.*[15] appears to be most recent estimate for HIV

($155 for tests on source-patient; $30 for counseling and record-keeping). Fourth, WC Lee *et al.*[6] themselves acknowledge their per-needlestick estimates are 'on the lower side' (p.1919). Nevertheless, the WC Lee[6] study is the first to produce national estimates and indicates that the great majority of needlesticks are relatively uncomplicated, incurring costs considerably less than the theoretically possible costs for severe needlesticks

***Table 3.** Lost work productivity*

Panel A. Needlesticks prior to subsequent infection (see Table 1)

1. Test SP only, find nothing
   129 099 cases times one hour lost at weighted wage for BLS category of 'Health Care and Social Assistance', $32.81; product equals $4 235 738
2. Test SP and HCW, including those infected
   a. Minimal testing. 81 763 × 2 hours × $32.81 = $5 365 288
   b. Substantial testing
      HBV test: 861 × 20 hours × $32.81 = $564 988
      HCV test: 2670 × 20 hours × $32.81 = $1 752 054
      HIV test: 775 × 60 hours × $32.81 = $1 525 665
      Subtotal: $3 842 707
3. Test HCW only, not SP, including those infected
   a. Moderate testing 99 229 × 10 hours × $32.81 = $32 557 034
   b. Substantial testing
      HBV test: 405 × 20 hours × $32.81 = $265 761
      HCV test: 1256 × 20 hours × $32.81 = $824 187
      HIV test: 364 × 60 hours × $32.81 = $716 570
      Subtotal: $1 806 518
4. Total: $4 235 738 + $5 365 288 + $3 842 707 + $32 557 034 + $1 806 518 = $47 807 285

Panel B. Subsequent infection

5. a. HBV chronic. Assumed from age 40 until retirement at age 65 that there will be a total of 3 extra months (1/4 of year, 500 hours) for assumed 50% of 34 chronic HBVs who survive beyond retirement : $318 206
   b. HBV chronic. Assumed 50% will die prematurely at age 60 and lose 5 years of wage-earning life as well as 20 hours lost per year due to morbidity until death: = $5 984 646
   c. HBV acute. 418 cases (see footnote #4 for HBV, for Table 2). Assumed 40 hours of work loss over lifetime. $548 583.
      Subtotal: 318 205 + 5 948 646 + 548 583 = $6 815 434
6. a. HCV chronic. Assumed from age 40 until retirement at age 65 that there will be a total of 3 extra months (1/4 of year, 500 hours) of days lost for the assumed 50% that survive beyond retirement. $1 338 345.
   b. HCV chronic. Assumed 50% will die prematurely at age 60 and lose 5 years of wage-earning life as well as 20 hours lost per year due to morbidity until death. $25 170 729
   c. HCV acute. 25 cases (see footnote #4 for HCV for Table 2). Assumed 40 hours of workloss over lifetime. $32 810.
      Subtotal: $1 338 345 + $25 170 729 + $32 810 = $26 541 884
7. a. HIV. Assumed from age 40 until death at age 65 there will be 6 extra months of days lost
      $22 853
   b. HIV. Assumed 0 years of wage-earning life lost from age 40 to age 65. $0. (24 year life expectancy from Schackman *et al.*[15])

Total for subsequent infection: $318 206+ $5 948 646 + $548 583 + $1 338 345 + $25 170 729 + $32 810 + $22 853 + $65 620 = $33 380 172

Panel C. Total indirect: $47 807 285 + $33 380 172 = $81 187 457

Panel A

1. The authors assumed zero lost productivity costs for HCWs who did not report or receive private testing. This 'zero' assumption applied only to testing costs. Some HCWs may not have received testing but nevertheless developed infection. The authors capture these HCWs in our 'subsequent infection' estimates below
2. To estimate a wage, the authors constructed a weighted average of nine of the major occupations listed in Shah *et al.*[7]: physician, nurse, laboratory technician, technologist, housekeeper, nursing aide, surgery attendant, dental assistant, and dentist. The weights were based upon these occupations average percentage contribution across the four data sets in Shah *et al.*'s[7] Table 1
3. Hours of work-loss may be interpreted as either physical or 'mental' absence. 'Mental' absence may result from anxiety and not working at usual capacity even while physically present at the job. 'Mental' absence is inversely measured by 'presenteeism.'[16] The authors assumed work loss for HIV testing would be three times the loss due to either HBV or HCV

Panel B

5a. The authors assumed a 40 year-old nurse would newly contract chronic infection. The authors assumed 50% would work full-time until retirement at age 65 and eventually die at age 70. The authors assumed 50% would die at age 60. For the group, this implied a life expectancy of 25 years from age 40 to age 65. (US life expectancy for women at age 40 is 41.6 years[38]) This 25 year life expectancy is consistent with the 18.85 to 19.40 Quality Adjusted Life Years for HCV in Salomon *et al.*[15], 24.8 to 27.9 life years for HBV in Wong *et al.*[33] and the 19.79 and 19.67 life expectancy for HBV and HCV in Marshall *et al.*[14]. We assumed wage inflation of 3% per year, productivity growth of 1% per year and a discount rate of 3% per year. These assumptions implied that real discounted wages were assumed to grow at 1% per year. For the 50% who work until retirement, we assumed the 500 hours of work productivity loss would be spread evenly across the 25 years until retirement, i.e. 20 hours per year

5b. For the 50% who die at age 60, 5 years of life lost means 2000 hours for each of 5 years after age 60. Expanding with 1% per year productivity from age 60 through age 65 yields $32.81 × 2000 hours × 5.142(1% adjusted years) = $337 418. Multiplying by the number of deaths, 34 × 50% × $337 418 yields $5 736 106. Assuming 20 hours lost per year until age 60 (20 years) yields $32.81 × 20 hours × 22.280(1 % adjusted years) = $14 620. Multiplying by the number in this category, 34 × 50% × $14 620 = $248 540. Adding to the premature death (adding morbidity plus mortality costs) yields $5 736 106 + $248 540 = $5 984 646

5c. 418 cases of acute HBV (see footnote #4 for HBV in Table 2). Assumed 40 hours of workloss over lifetime. 418 × 40 × $32.81 = $548 583

6a. See footnote #5a above. 20 hours × $32.81 wage × 28.525 (1% adjusted years) × 143 HCWs with chronic HCV × 50% assumed to live = $1 338 345

6b. See footnote #5b above. For mortality costs: $32.81 × 2000 hours × 5.142(1% adjusted years) × 143 HCWs with chronic HCV × 50% who die = $24 125 389. For additional morbidity costs: $32.81 × 20 hours per year × 22.280(1% adjusted years) × 143 HCWs with chronic HCV × 50% who die at age 60 = $1 045 340. Adding mortality with morbidity costs: $24 125 389 + $1 045 340 = $25 170 729

6c. 25 cases of acute HCV (see footnote #4 for HCV in Table 2). Assumed 40 hours of workloss over lifetime. 25 × 40 × $32.81 = $32 810

7a. 1000/25 = 40 hours evenly distributed across 25 years. 62.5 × 17 431 (1% adjusted years) × $32.81 wage × 1 patient equals $22 852.82 for morbidity

7b. The authors assumed HCW would exceed Schackman *et al.*[15] estimate given HCW's access to and knowledge of high quality medical care

Table 4. *Combined numbers and costs for needlesticks and HBV, HCV, HIV infections*

Base-case estimate for 2004
Medical
Number of needlestick injuries: 644 963
Number of needlestick injuries generating costs: 316 419 (49% of 644 963)
Cost for testing and prophylaxis only: $103 125 746
Average medical cost per tested needlestick prior to infection: $326
Number subsequent infections generating medical costs: 178 (34 for chronic HBV, 143 for chronic HCV, 1 for HIV)
Cost of subsequent infections: $4 186 548 ($924 188 for HBV, $2 877 160 for HCV, $385 200 for HIV)
Subtotal cost for testing, prophylaxis, and infections: $107 312 294
Percent of total cost due to testing and prophylaxis only: 95.9%
Average medical cost per tested needlestick: $107 312 294/316 419 = $339
Lost work productivity
Testing and prophylaxis only: $47 807 285 (59% of subtotal)
Subsequent infection: $33 380 172
Subtotal: $81 187 457
Grand total (for testing, prophylaxis, subsequent infection and for medical and lost work costs): $188 499 751
Medical only: 56.9%
Average total cost per tested needlestick: $188 499 751/316 419 = $596
Testing and prophylaxis only: $150 933 031 (80% of total)

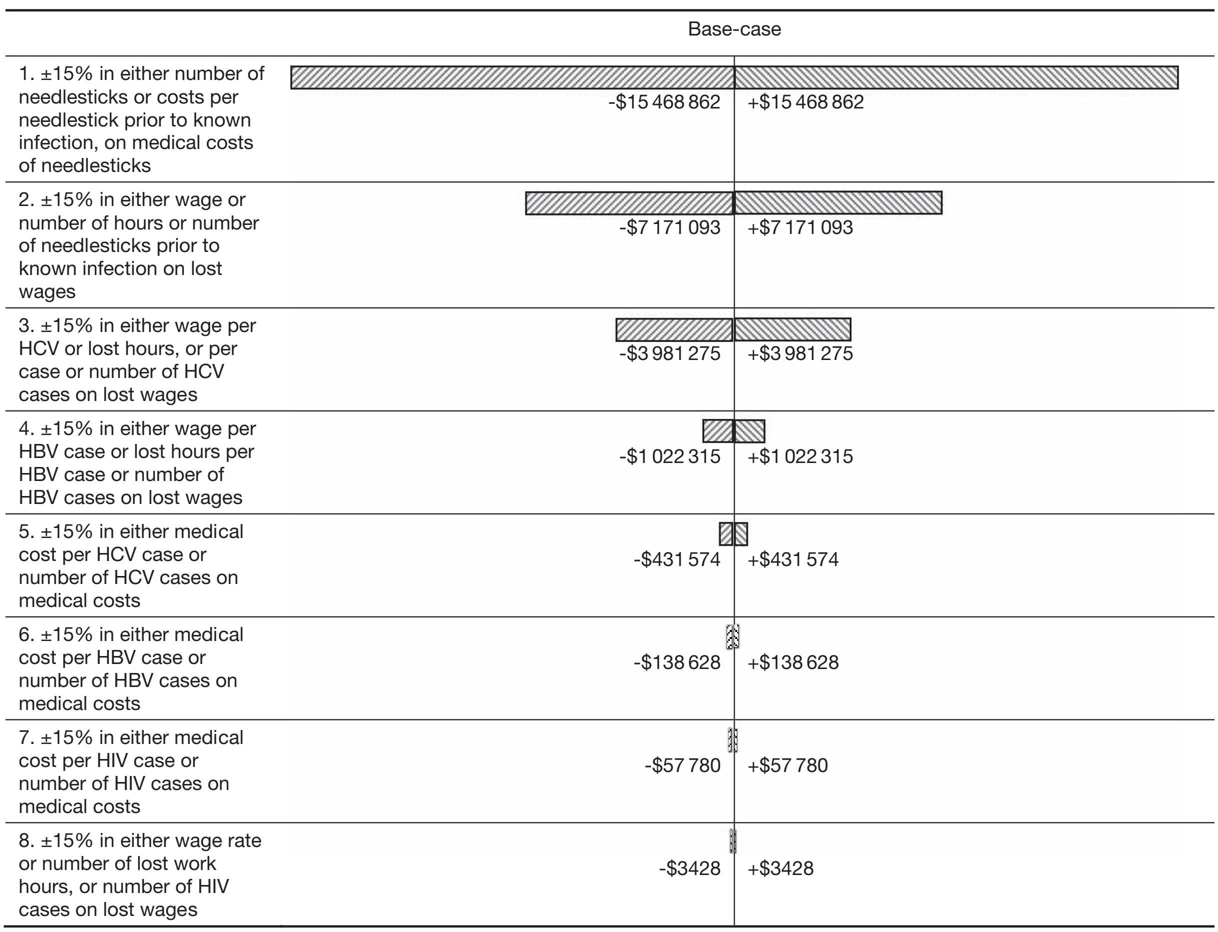


Figure 2. *One-way sensitivity analysis on ± 15% variation in influential variables*

detailed in some studies reviewed by JM Lee[5]. The finding that the great majority of needlesticks are relatively uncomplicated was confirmed by our personal knowledge of reporting to the Bloodborne Pathogen Surveillance Nurse, Employee Health Department at the University of California-Davis Medical Center.

Fisman *et al.*[25] present a willingness-to-pay median estimate of $1011 (2004) per needlestick avoided. Applying $1011 to our estimate of tested and

Table 5. *Case-study sensitivity analysis*

		Medical costs	Lost work productivity	Combined
Lower bound scenarios				
1.	Panlilio *et al.*[3] estimate lower bound 19% below their best estimate for numbers of needlesticks; we also applied to subsequent infections	–19.0% –$20 389 335	–19.0% –$15 440 533	–19.0% –$35 829 868
2.	Assume a 45.1% reduction in average cost per NI prior to subsequent infections (JM Lee[5] citation to Holodnick and Barkanskas[11])	–45.1%, –$46 509 713	0	–$46 509 713
3.	Assume a 50% reduction in lost work productivity and applied to subsequent infections	0	–50% –$40 632 984	–$40 632 984
4.	Assume a reduction in reporting rate on needlesticks from 43.4 to 40% in Figure 1 and Table 1 and applied to subsequent infections	–6.2% –$6 653 362	–6.2% –$5 038 490	–6.2% –$11 691 852
5.	HBV. Assume 45% rather than 70% of occupational exposures due to needlesticks; 5% rather than 7.5% of HBV needlesticks become chronic; cost per HBV infection reduced by ratio of Marshall *et al.* estimate to our base-case and applied to subsequent infections only, not testing	–77.3% –$714 055	–54.4% –$3 713 494	–$4 212 249
6.	HCV. Assume a 50% reduction in incidence and a 42.4% reduction in cost-per-case and applied to subsequent infections only, not testing	–71.2% –$2 048 538	–50% –$13 254 537	–$15 303 075
7.	HIV. Assume zero cases and applied to subsequent infections only, not testing	–100% –$385 200	–100% –$22 853	–$408 053
Upper bound scenarios				
8.	Panlilio *et al.*[5] estimate an upper bound 20.7% above their best estimate for number of needlesticks; we also applied to subsequent infections	+20.7% +$22 213 644	+20.7% +$16 822 055	+20.7% +$39 035 699
9.	Assume $719 per needlestick prior to subsequent infection. Assume applied to medical cost only. JM Lee *et al.*[5] citation to Dale *et al.*[36]	+120.55% +$124 318 071	0%	+$124 318 071
10.	Assume a 50% increase in lost work productivity	0	+50% +$40 632 984	+$40 632 984
11.	Assume an increase in reporting rate on needlesticks from 43.4 to 50% in Figure 1 and Table 1	+12.1% +$12 984 787	+12.1% +$9 833 182	+12.1% +$22 817 969
12.	HBV. Assume 90% rather than 70% of occupational exposures due to needlesticks; 10% rather than 7.5% of HBV needlesticks become chronic; cost per HBV infection increased by ratio from Marshall *et al.*[12]and HCV estimate from Salomon *et al.*[13] estimate to our base-case and applied to subsequent infections only, not testing	+113.05% +$1 044 796	+67.2% +$4 587 583	+$5 632 379
13.	HCV. 50% increase in incidence; 24.3% increase in medical costs	+86.5% +$2 487 305	+50% +$13 270 942	+$15 758 247
14.	HIV. Incidence increase from 1 to 3 (200%)	+200% +$770 400	+200% +$45 706	+$816 106

non-tested needlesticks (644 963) yields roughly $652 million. This $652 million willingness-to-pay estimate and our $188.5 million cost-of-illness estimate are consistent with theory and findings that cost-of-illness estimates are considerably less than willingness-to-pay estimates[24,26]. The disparity between willingness-to-pay and cost-of-illness estimates is likely to be great for needlesticks. There is considerable fear associated with HBV, HCV and HIV; given the latency of these infections, the fear can last 6 months or longer.

Our estimates are consistent with the literature. Our 644 963 needlesticks compares to the 600 000–800 000 earlier CDC estimate for the 1990s[27]. Our use of Panlilio *et al.*'s[3] estimate of 56.6% under-reporting compares to a conclusion in NIOSH Alert[28] that cites four studies suggesting 'about half of these injuries go unreported.' This 56.6% under-reporting is a little higher than other

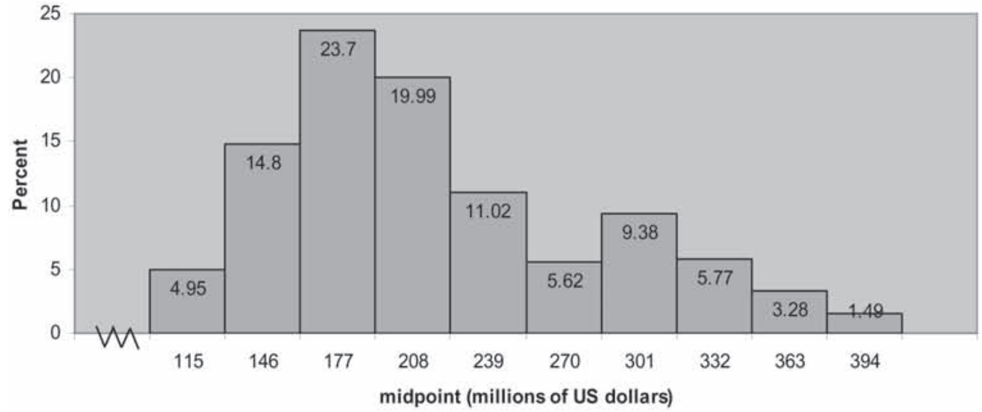


Figure 3. *Histogram for multi-way probabilistic sensitivity analyses*

occupational injuries[29] but is consistent with the idea that HCWs believe many needlesticks can be rectified with 'immediate disinfection of the wound,'[30] or HCWs judge the needlestick to be a 'very low risk of transmission[30] or HCWs worry that needlesticks signify incompetence[31]. Pruss-Ustun *et al.*[32] estimate 390 new annual HCV infections to HCWs in the US, Canada and Cuba combined. If we adjust for (1) population sizes across countries, (2) the 29% HCV incidence decline from 2000 to 2004, and (3) only 85% become chronic, then the adjusted Pruss-Ustun[32] estimate would be 228 which is not far from our 143 estimate. Our 25 year life expectancy for HCWs (who are predominately female, well-educated, and medically-compliant) newly diagnosed with chronic HBV and HCV compares with the 19 adjusted life years for HCV in Salomon *et al.*[14], the 25–28 life years for HBV in Wong *et al.*[33] and the 20 years for HBV and HCV in Marshall *et al.*[13] for 27-year-olds.

Our study has strengths. We used national, BLS estimates on employment and wages as opposed to local or regional estimates and we used BLS data that combined private with government employment. Our counting method for HBV, HCV, and HIV implicitly included anyone not tested yet who eventually developed disease. For example, incidences of HBV and HCV were estimated from CDC data (MJ Alter e-mail 11/15/06), from Sepkowitz and Eisenberg[8] in a recent article specifically addressing occupational deaths among HCWs, and from Do *et al.*[12] who collected data over 20 years on HCWs with HIV. Our estimates of medical costs in testing and prophylaxis and our estimates of treatment of infection were independently derived. The infection data from CDC, Sepkowitz and Eisenberg[8] and Do *et al.*[12] did not distinguish between infection from HCWs who had been tested after needlestick versus those who were not tested. As a result, our 'implicit' inclusion of those not tested could not distinguish between costs or numbers of infected HCWs who had been tested after a needlestick versus those who had not been tested.

Additional strengths included the fact that our lifetime costs for HCV and HIV were within the ranges provided in the literature review for counting needlesticks, infections and costs[4–13,33–41]. We also used the mean from eight studies rather than a single study to estimate costs-per-needlestick before treatment for known infection. This mean was then calibrated to different source-patient scenarios using the study with the most detail on costs and source-patient status[9].

In addition, we constructed three sensitivity analyses. The first two were one-way sensitivity analyses. The first, using the 'tornado' diagram (Figure 2) indicated which among eight variables were most influential for the same percentage change (15%). The second (case-study method) used alternate values derived from the literature. We believe these approaches were complimentary. Finally, our multi-way Monte Carlo sensitivity analysis allowed for varying values and probabilities of values. This technique generated a histogram with a long right tail. This long right tail was consistent with the distribution of medical costs across a wide array of medical conditions[41]. A few cases were extremely costly. Finally, our methods were transparent.

Our study has limitations. There are no estimates of combined costs of needlesticks outside hospitals. We produced our own based on differing needlestick rates inside and outside hospitals. We sometimes used professional judgment to generate ratios and percentages in Figure 1 and Tables 1–4, but these were clearly delineated and, in most cases, inconsequential. For example, a number of different percentages were considered in the lower half of Figure 1. However, provided costs-per-needlestick were relatively similar across disease categories and provided relatively small percentages of source-patients and HCWs were infected, the effects on costs estimates of varying assumptions in the lower half of Figure 1 were minimal.

We did not take the societal perspective. The lost productivity analysis ignored lost home production, willingness-to-pay, and pain and suffering costs. But measurements of these are controversial. Overall, however, given the dearth of literature on work-loss due to needlesticks, HBV and HCV, we have less confidence in our lost productivity estimates than our medical cost estimates.

There were other limitations. Following Sepkowitz and Eisenberg[8], we assumed the proportion of source-patients with possible infections was the same as the proportion in the US population. Our base-case used 3.9 million for hepatitis C rather than 2.7 million for chronic hepatitis C. We reasoned that the 3.9 million number more accurately reflected risk factors for source-patients (such as being an ex-convict, or drug-user, or having numerous sex partners or numerous tattoos) in addition to chronic hepatitis C that would have triggered additional testing for the HCW. Following Gerberding[1], we assumed the Panlilio *et al.*[3] estimate from the late 1990s applied to the 2000s. On the one hand, given increased attention to needlesticks, we might expect fewer needlesticks over time. On the other hand, employment of HCWs increased every year. The Gerberding assumption implied that incidence did not decline, but that risk per HCW did decline. Following Sepkowitz and Eisenberg[8], we ignored simultaneous infection of HCV and HIV. But given new HIV among HCWs is rare, this limitation appears small. Finally, we did not estimate costs outside the healthcare industry.

Conclusion

We estimated 644 963 needlesticks occurred to HCWs within the entire healthcare industry, not just hospitals, in 2004. Total costs for these needlesticks, including subsequent infections, were $188.5 million of which 57% were medical costs and 43% were lost-work productivity costs. This $188.5 million was roughly 0.1% of the cost of all occupational injuries and illnesses. Subsequent HBV, HCV, and HIV infections comprised 20% of the total, largely representing lost-work productivity. Only roughly 4% of medical costs were attributed to subsequent infections. Sensitivity analysis suggested assumptions regarding numbers of needlesticks, cost-per-needlestick and lost productivity were especially important in generating varying estimates.

Whereas specific numbers and assumptions are likely to be refined in light of new findings[42], we believe the model (the ‘boxes’ and categories in our figures and tables) will prove useful to future researchers. The costs of preventing needlesticks with safer devices and training are important topics for future research.

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References

1. Gerberding JL. Occupational exposure to HIV in health care settings. N Engl J Med 2003;348:826-33
2. Louie T. Occupational hazards. N Engl J Med 2005;353:757-9
3. Panlilio AL, Orelien JG, Sirvastava PU, et al. Estimate of the annual number of percutaneous injuries among hospital-based healthcare workers in the United States, 1997-1998. Infect Control Hosp Epidemiol 2004;25:556-62
4. U.S. Bureau of Labor Statistics, Occupational Employment and Wage Estimates, www.bls.gov/oes/current/oessrci.htm#62. (accessed 3/5/07)
5. Lee JM, Botteman MF, Xanthakos N, Nicklasson L. Needlestick injuries in the United States. Epidemiologic, economic, and quality of life issues. AAOHN J 2005;53:117-33
6. Lee WC, Nicklasson L, Cobden D, et al. Short-term economic impact associated with occupational needlestick injuries among acute care nurses. Curr Med Res Opin 2005;21:1915-22
7. Shah SM, Bonauto D, Silverstein B. Workers’ compensation claims for needlestick injuries among healthcare workers in Washington State, 1996-2000. Infect Control Hosp Epidemiol 2005;26:775-81
8. Sepkowitz KA, Eisenberg L. Occupational deaths among healthcare workers. Emerg Infect Dis 2005;11:1003-8
9. Orenstein R, Reynolds L, Karabaic M, et al. Do protective devices prevent needlestick injuries among health care workers? Am J Infect Control 1995;23:344-51
10. U.S. Bureau of Labor Statistics. Consumer Price Index. All Urban Consumers, Medical. www.bls.gov/cpi/home.htm, accessed 1/9/07
11. Holodnick CL, Barkanskas V. Reducing percutaneous injuries in the OR by educational methods. AAORN J 2000;72:461-72
12. Do AN, Ciesielski CA, Metler RP, et al. Occupationally acquired HIV infection: national case surveillance data during 20 years of the HIV epidemic in the U.S. Infect Control Hosp Epidemiol 2003;24:86-96
13. Marshall DA, Kleinman SH, Wong JB, et al. Cost-effectiveness of nucleic acid test screening of volunteer blood donations for hepatitis B, hepatitis C, and human immunodeficiency virus in the United States. Vox Sang 2004;86:28-40
14. Salomon JA, Weinstein MC, Hammitt JK, Goldie SJ. Cost-effectiveness of treatment for chronic hepatitis C infection in an evolving patient population. J Am Med Assoc 2003;290:228-37
15. Schackman BR, Gebo KA, Walensky RP, et al. The lifetime cost of current human immunodeficiency virus care in the United States. Med Care 2006;44:990-97
16. Goetzel RZ, Long SR, Ozminkowski RJ, et al. Health, absence, disability, and presenteeism cost estimates of certain physical and mental health conditions affecting US employers J Occup Environ Med 2004;46:398-412
17. Gillen M, McNary J, Lewis J, et al. Sharps-related injuries in California health care facilities: pilot study results from the sharps injury surveillance registry. Infect Control Hosp Epidemiol 2003;24:113-21

18. Cotran RS, Kumar V, Collins T., eds. Robbins Pathologic Basis of Disease, 6th edn, Ch 19: The liver and biliary tract. New York, NY: WB Sanders, 1998
19. Bucuvalas JC, Zeng L, Anand R. Predictors of length of stay for pediatric liver transplant recipients. Liver Transpl 2004;10:1011-17
20. Insinga RP, Dasbach EJ, Elbasha EH. Assessing the annual economic burden of preventing and treating anogenital human papillomavirus-related disease in the U.S.: analytic framework and review of the literature. Pharmacoeconomics 2005;23:1107-22
21. Huse DM, Schulman K, Orsini L, et al. Burden of illness in Parkinson's disease. Mov Disord 2005;20:1449-54
22. Waehrer G, Leigh JP, Miller TR. Costs of occupational injury and illness within the health services sector. Int J Health Serv 2005;35:343-59
23. U.S. Bureau of Labor Statistics. Occupational Injuries and Illnesses: Counts, Rates, and Characteristics, 1992. Bulletin number 2455. U.S. Dept of Labor, Washington D.C. U.S. Government Printing Office, 1995
24. Leigh JP, Markowitz SB, Fahs MC, PJ Landrigan. Cost of Occupational Injuries and Illnesses. Ann Arbor MI: University of Michigan Press, 2000
25. Fisman DN, Mittleman MA, Sorock GS, Harris AD. Willingness to pay to avoid sharps-related injuries: a study in injured health care workers. Am J Infect Control 2002;30:283-7
26. Goddeeris JH. Theoretical considerations on the cost of illness. J Health Econ 1983;7;149-59
27. U.S. Dept. of Health and Human Services, Healthy People 2010 (Conference Edition in Two Volumes), Washington DC. January 2000
28. NIOSH Alert. Preventing needlestick injuries in health care settings. DHHS (NIOSH) Publication No. 2000-108, Nov 1999 (www.cdc.gov/niosh/2000-108.html) (accessed 11/28/05)
29. Leigh JP, Marcin JP, Miller TR. An estimate of the U.S. government's undercount of nonfatal occupational injuries. J Occup Environ Med 2004;46:10-18
30. Rabaud C, Zanea A, Mur JM, et al. Occupational exposure to blood: Search for a relation between personality and behavior. Infect Control Hosp Epidemiol 2000;21:564-74
31. Elmiyeh B, Whitaker IS, James MI, et al. Needlestick injuries in the National Health Service: a culture of silence. J R Soc Med 2004;97:326-7
32. Pruss-Ustun A, Rapiti E, Hutin Y. Estimation of the global burden of disease attributable to contaminated sharps injuries among health care workers. Am J Indust Med 2005;48: 482-90
33. Wong JB, Koff RS, Tine F, Pauker SG. Cost-effectiveness of interferon-alpha-2b treatment for hepatitis B e antigen-positive chronic hepatitis B. Ann Intern Med 1995;122:664-75
34. Kanwal F, Gralnek IM, Martin P, et. al. Treatment alternatives for chronic hepatitis B. Ann Internal Med 2005;142:821-31
35. Crowley S, Tognarini D, Desmond P, et al. Introduction of lamivadine for treatment of chronic hepatitis B: Expected clinical and economic outcomes based on 4-year clinical trial data. J Gastroenterol Hepatol 2002;17:153-64
36. Yazdanpanah Y, Goldie SJ, Losina E, et al. Lifetime cost of HIV care in France during the era of highly active antiretroviral therapy. Antivir Ther 2002;7:257-66
37. Leigh JP, Bowlus CL, Leistikow BN, Schenker MB. Costs of hepatitis C. Arch Intern Med 2001;161:2231-7
38. Arias E. United States life tables, 2003. National Vital Statistics Reports vol. 54, no. 14. Hyattsville, MD: National Center for Health Statistics, 2006
39. Dale JC, Pruett SK, Maker MD. Accidental needlesticks in the phlebotomy service of the Department of Laboratory Medicine and Pathology at Mayo Clinic Rochester. Mayo Clin Proc 1998;73:611-15
40. Centers for Disease Control. Updated U.S. Public Health Service guidelines for the management of occupational exposures to HBV, HCV, and HIV and recommendations for postexposure prophylaxis. MMWR Morb Mortal Wkly Rep 2001;50(RRII): 1-42
41. Mullahy J. Much ado about two: reconsidering retransformation and the two-part model in health econometrics. J Health Econ 1998;17:247-81
42. Makary MA, Al-Attar A, Holzmueller CG, et al. Needlestick injuries among surgeons in training. New Engl J Med 2007;356:2693-9

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