Improving outcomes and reducing costs by modular training in infection control in a resource-limited setting

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Accepted for publication 12 September 2012

Abstract

Objectives. To study the impact of modular training and implementation of infection control practices on all health-care-associated infections (HAIs) in a cardiac surgery (CVTS) program of a tertiary care hospital.

Design. Baseline data were compared with post-intervention (with modular training) data.

Settings. This study was conducted in a cardiovascular surgical unit.

Participants. In total, 2838 patients were admitted in cardiovascular surgical service.

Interventions. Two training modules and online continuous education were delivered to all health-care workers in CVTS unit.

Main Outcome Measures. All four HAIs, such as surgical site infections (SSI), central line-associated blood stream infection (CLABSI), ventilator-associated pneumonia (VAP) and catheter-associated urinary tract infections (CA-UTI), were studied. Additional outcome measures included average length of stay cost of avoidance mortality and readmission rates.

Results. The SSI rate had decreased in the post-intervention phase from 46 to 3.27% per 100 surgeries (P < 0.0001), CLABSI had decreased from 44 to 3.10% per 1000 catheter days (P < 0.009), VAP was reduced from 65 to 4.8% per 1000 ventilator days (P < 0.0001) and CA-UTI had reduced from 37 to 3.48% per 1000 urinary catheter days (P < 1.0). For every $1 spent on training, the return on investment was $236 as cost of avoidance of healthcare associated infections (HAIs).

Conclusions. Standardization of infection control training and practices is the most cost-effective way to reduce HCAIs and related adverse outcomes.

Keywords: health-care-associated infections, surveillance, training and hospital cost

Introduction

Health-care-associated infections (HAIs) are among the most vital patient safety issues in health care today. The four common HAIs that are typically studied using standardized definitions include surgical site infections (SSI), central line-associated blood stream infections (CLABSI), ventilator-associated pneumonia (VAP) and catheter-associated urinary tract infections (CA-UTI). Together, they contribute substantially to mortality, morbidity and health-care costs in all environments [1–4]. In the USA alone, the incidence of HAIs has been estimated to be approximately 2 million cases annually [1] with approximately 99 000 HAI-attributable deaths, making it as the fifth leading cause of death in acute care hospitals [2]. The magnitude of the problem of HAIs has resulted in concerted efforts to reduce its incidence and impact in many industrialized nations [5]. Standardized criteria for surveillance and control of HAIs have been developed. Surveillance systems, structured training programs and standardized infection control policies have been instituted in most hospitals in a systematic effort toward minimizing patient morbidity and mortality and costs of all four HAIs [6–8].

Among developing countries, data on HAIs are limited, and these suggest differences in prevalence, profile and awareness when compared with developed countries [9–11]. These include a relatively high prevalence of Gram-negative organisms in most hospitals in developing nations, lack of standardized infection control protocols and inadequate formal training for health-care professionals, including
physicians. HAIs and infection control are still not a part of standard medical school curriculum. With growing sophistication of tertiary health-care industry in the developing world, there is an urgent need to test and develop standardized, cost-effective infection control practices using available human and material resources. In these environments, improved awareness and standardized infection control practices may require a relatively small investment and are likely to have a substantial impact.

This study prospectively examined the impact of modular training in infection control practices on process measures, outcomes and costs of care of four HAIs (SSI, CLABSI, VAP and CA-UTI) in the department of cardiovascular surgery of a large tertiary care referral hospital in South India.

Methods

The study design was a pre- vs. post-comparison of a training intervention. Data were collected using standardized Center for Disease Control (CDC) National Healthcare Security Network protocols, and CDC definitions for SSI, CLABSI, VAP and CA-UTI, process and outcome measures were followed [12, 13]. The infection was regarded as hospital acquired if it occurred within 48 h of admission to the hospital. All HAI data were collected and collated by the infection control team.

Setting

The study was conducted in the adult cardiovascular surgery unit in a tertiary care referral university teaching hospital in South India (Table 1). The institute is a charitable (not-for-profit) hospital, serving the state population of 30 million and 4 nearby states. The average annual per capita income of the population served is $1444. The vast majority of admitted patients do not have health insurance [4]. Hospital expenses are either partially or completely subsidized by the hospital for patients with limited income. Most of the remaining patients meet hospital expenses from their personal resources (out-of-pocket). The laboratory in the institute is nationally accredited by the National Board of Accreditation for Laboratories.

Institutional ethics approval

Prior approval by the Scientific Review Committee and Institutional Ethics Committee was obtained before initiating the study.

Constitution of the infection control team

Before the study began, there were no formal infection control practices and no structured training program for staff. An infection control committee met on an ad hoc basis in response to infection outbreaks. In the pre-intervention phase, only two members were focused on point surveillance in high-risk areas or on demand basis and they had received no formal training or certification. We constituted a special team comprising three infection control nurses and two microbiologists, along with a data entry operator. They received structured training through visits by an international expert prior to the initiation of the training programs. Training modules were created with the help of the expert. (Details included in Table 2.)

Study population and sample size

All adult patients (2838) undergoing cardiovascular surgical procedures during the study period (January 2009–December 2010) were included.

Intervention

The two-module training step-by-step teaching program was developed by the infection control team under the guidance of the faculty members of the infection control committee. Training was imparted to all 184 health-care workers who

Table 1 Overview of the study population in the cardiovascular surgery unit

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-intervention</th>
<th>Post-intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed strength of ICU</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Bed strength of ward</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Staff strength and composition</td>
<td>92 (ICU), 50 (OR), 42 (ward)</td>
<td>90 (ICU), 50 (OR), 41 (ward)</td>
</tr>
<tr>
<td>Patient turnover</td>
<td>1434</td>
<td>1404</td>
</tr>
<tr>
<td>Average number of operations/day</td>
<td>5.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Patient days</td>
<td>12,486</td>
<td>11,350</td>
</tr>
<tr>
<td>Days in ICU</td>
<td>7,929</td>
<td>7,675</td>
</tr>
<tr>
<td>Mean age in years</td>
<td>57.1 ± 10.1</td>
<td>58.1 ± 10.1</td>
</tr>
<tr>
<td>Gender distribution</td>
<td>64% (Males) 36% (Females)</td>
<td>70% (Males) 30% (Females)</td>
</tr>
<tr>
<td>Mean APACHE score</td>
<td>74</td>
<td>72</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>68%</td>
<td>71%</td>
</tr>
<tr>
<td>Diabetes with renal failure</td>
<td>8%</td>
<td>8%</td>
</tr>
</tbody>
</table>

APACHE, acute physiologic and chronic health evaluation; OR, operation room.
included surgeons, anesthesiologists, perfusion technologists, nurses (in operating rooms, intensive care and wards), operating room technicians and housekeeping staff in two modules over a 4-month period. Twenty-two percent of the nursing staff was semiskilled or partially trained. The infection control nurse recorded the objectives achieved, the time spent and the tests taken after each module. Knowledge, attitude and practices were studied at baseline (pre-test), immediately after completion of training and after 3 months of training. Baseline infection rates, clinical outcomes and process surveillance parameters were measured over the initial 12 months and this included the 4-month training period. Post-intervention data were collected on the same parameters for 1 year thereafter. Audits to analyze changes in behavioral practices were also done for the period of 1 year in the post-intervention period.

Education program

Two modules appropriate for all health-care personnel were planned as two half-day training programs with all faculty and staff in CVTS. The training sessions were in the form of didactic sessions, video shows, quizzes, role plays and tests (Table 2). All attendees (184) took the test at baseline (pre-intervention), at the end of the training and after 3 months of the first training. High compliance was ensured through a mandate from the hospital administration. Because multiple sessions were organized in various batches, there were adequate opportunities for all the members of the team to attend the sessions. Module 2 was more difficult (specific) than Module 1 (general).

Each test paper had 20 multiple-choice questions with four alternatives answers. The test questions remained the same during three levels of testing (pre, post and 3 months after post-test evaluation) per module. Education, monitoring of compliance and feedback were important components of establishing infection control process.

Data

Within the outcome surveillance component, data were classified into:

- HAIs rates, excess length of stay, cost of training and surveillance, direct and indirect cost of each HAI, cost of avoidance of HAIs, readmission rate, and crude and excess mortality rate.
- The process surveillance component includes the following data points: pre- and post-tests, tests after 3 months,
audits on hand hygiene compliance, isolation precautions and wound care and performance and training feedback.

Data collection
The infection control team and the charge nurses (link nurse for infection control in intensive care units (ICUs) and wards) were involved in the data collection. The infection control team designed the surveillance sheet after conducting a pilot study. All SSI patients were followed up by the medical social workers for 30 days from the date of surgery. All other HAIs were followed up until discharge from hospital. The infection control team exclusively evaluated all patients, devices, culture reports, clinical parameters, along with other outcome measures.

Microbial analysis
All samples for microbial analysis were collected using standard guidelines. Blood cultures were processed using the automated Bactec systems (BD, NJ, USA).

Cost estimations
For each infected patient, both direct and indirect costs were estimated (Table 3). Direct costs include service cost (inclusive of procedure cost, operating room and anesthesia charges), cost of daily bed stay, drugs, laboratory tests, radiology investigations and miscellaneous expenses such as blood transfusion and cross-consultation, if any. The indirect cost component was arrived at after rigorous follow-up by the departmental medical social worker. Information on patients with symptoms of SSI after discharge was captured and this included records of visits to other facilities in the region. Indirect costs included cost of the job days lost by the patient and the accompanying family member, cost of stay of the family member and expenses for food and other miscellaneous items. Opportunity cost includes the real cost of the output foregone, lost patient days and cost of other benefits that provide utility using a standardized format.

Table 3 Details of cost variables

<table>
<thead>
<tr>
<th>No.</th>
<th>Cost variables</th>
<th>Costing parameters</th>
</tr>
</thead>
</table>
| 1   | Direct cost    | (a) Surgical procedure cost
|     |                | (b) Operating room cost
|     |                | (c) Anesthesia cost
|     |                | (d) ICU and ward charges
|     |                | (e) Medicines
|     |                | (f) Lab investigations
|     |                | (g) Radiology investigation
|     |                | (h) Blood transfusion
|     |                | (i) Cross consultations (if any)
|     |                | (j) Any other procedure charges (like dialysis)
| 2   | Indirect cost  | (a) Loss of job days of patient
|     |                | (b) Loss of job days of attendants
|     |                | (c) Boarding and lodging cost of attendants
|     |                | (d) Miscellaneous charges (like transportation)
| 3   | Cost of additional LOS | (a) Cost involved for extra stay of HAI patients
| 4   | Opportunity cost | (a) Cost of lost opportunity of admitting additional patients because of occupied beds by HAI patients
|     |                | (b) Cost of lost opportunity of doing more surgical procedures because of beds been occupied by HAI patients

LOS, length of stay.

Results
Data were prospectively collected on 1434 patients (11,350 patient days) in the cardiovascular surgical unit during the year before intervention and on 1404 patients (5675 ICU days) in the post-intervention year with results as shown in Table 1. The age, co-morbidity profile of patients and out-of-pocket expense group were not significantly different between pre- and post-intervention periods. Out of 184 health-care workers, only 3 left the CVTS ICU during the study period. All others attended the pre-, post-training and 3-month training sessions. The performance scores (out of a maximum of 20 points) of the staff members before and after the training sessions were 10.2 ± 4.4 in the pre-test, 18.5 ± 2.1 in post-test and 18.7 ± 1.8 in the test performed 3 months later (P < 0.0001).

Process surveillance measures
Statistically significant improvements occurred in all process surveillance measures after intervention as indicated in the time series analysis (Table 4). The overall hand hygiene rates improved from 54 ± 11 to 82 ± 11%, isolation precautions
Table 4  Time series analysis for process and outcomes measurables of HAIs

<table>
<thead>
<tr>
<th></th>
<th>Before intervention</th>
<th></th>
<th>After intervention</th>
<th></th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AGR 1</td>
<td>Trend values</td>
<td>AGR 2</td>
<td>Trend values</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
</tr>
<tr>
<td>Process measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand hygiene compliance (%)</td>
<td>-0.01</td>
<td>54.04</td>
<td>54</td>
<td>54.03</td>
<td>54.02</td>
</tr>
<tr>
<td>Isolation precautions (%)</td>
<td>0.07</td>
<td>49.47</td>
<td>49.5</td>
<td>49.54</td>
<td>49.58</td>
</tr>
<tr>
<td>Wound care (%)</td>
<td>0.02</td>
<td>61.02</td>
<td>61</td>
<td>61.05</td>
<td>61.07</td>
</tr>
<tr>
<td>Outcome measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Readmission (%)</td>
<td>4%</td>
<td>2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection rate (per/100 surgeries)</td>
<td>-0.25</td>
<td>6.47</td>
<td>6.47</td>
<td>6.46</td>
<td>6.46</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>0.11</td>
<td>21.84</td>
<td>21.9</td>
<td>21.9</td>
<td>21.93</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>-1.59</td>
<td>1.32</td>
<td>1.31</td>
<td>1.3</td>
<td>1.29</td>
</tr>
<tr>
<td>Blood stream infections (CLABSI)</td>
<td>1.82</td>
<td>5.4</td>
<td>5.5</td>
<td>5.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Blood stream infection rate (/1000 central line days)</td>
<td>-0.14</td>
<td>1.18</td>
<td>1.18</td>
<td>1.18</td>
<td>1.17</td>
</tr>
<tr>
<td>Device utilization ratio</td>
<td>0.11</td>
<td>15.7</td>
<td>15.7</td>
<td>15.76</td>
<td>15.79</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>-0.34</td>
<td>0.88</td>
<td>0.88</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>VAP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection rate (/1000 ventilator days)</td>
<td>-1.09</td>
<td>13.92</td>
<td>13.8</td>
<td>13.65</td>
<td>13.51</td>
</tr>
<tr>
<td>Device utilization ratio</td>
<td>2.18</td>
<td>1.65</td>
<td>1.69</td>
<td>1.72</td>
<td>1.76</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>-0.08</td>
<td>25.71</td>
<td>25.7</td>
<td>25.68</td>
<td>25.67</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>1.18</td>
<td>3.4</td>
<td>3.36</td>
<td>3.31</td>
<td>3.27</td>
</tr>
<tr>
<td>Urinary tract infection (CA-UTI)</td>
<td>-0.56</td>
<td>5.61</td>
<td>5.57</td>
<td>5.53</td>
<td>5.49</td>
</tr>
<tr>
<td>Infection rate (/1000 catheter days)</td>
<td>1.07</td>
<td>0.82</td>
<td>0.81</td>
<td>0.8</td>
<td>0.79</td>
</tr>
<tr>
<td>Device utilization ratio</td>
<td>1.08</td>
<td>16.86</td>
<td>16.8</td>
<td>16.64</td>
<td>16.53</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>17.46</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
</tr>
</tbody>
</table>

AGR 1, annual growth rate (pre-intervention); AGR 2, annual growth rate (post-intervention); Q1–Q4, from Quarter 1 to Quarter 4.
improved from 50 ± 11 to 79 ± 11% and wound care improved from 61 ± 8 to 85 ± 5%.

Outcome measures

Table 4 shows the time trends of the various HAIs and device utilization ratios before and after the intervention. The overall rates of all HAIs, device utilization ratios and length of stay reduced significantly in all inter-quarter comparisons.

Impact on mortality

The total surgical mortality was 2.65% in the pre-intervention period and 1.99% in the post-intervention period. This difference was not statistically significant; however, among the individual categories of HAIs, mortality reductions from SSI, CLABSI and VAP were statistically significant (Table 4).

Cost

The total expense of training for all faculty and staff members, surveillance cost and room rent cost as per specifications was $1823. The outlay of one session of infection control training was $15. Cost of training of each individual staff was $5. VAP was the most expensive HAI with an extra expense of $1358 followed by SSI at $1173; CLABSI at $843 and CA-UTI at $561. Direct cost and indirect cost were studied for each HAI. The cost of infection per patient was $4960. The split-up was $5396 for SSI, $4772 for CLABSI, $6964 for VAP and $6481 for CA-UTI. Direct cost varied with the pattern of infection and the length of stay. The highest indirect cost was in VAP $563 and the lowest was in UTI patients $394.

Additional cost savings because of reduction in infection rates and bed days were $108,955. The opportunity cost related to freeing resources to operate on additional patients was $190,656, whereas per patient the savings on opportunity cost were $2243. Specific details on costs are available in Table 5. The total savings from reduction in occurrence of these four infections were $431,518. For every dollar spent on training, $236.70 was the return on investment through prevention of infection.

Discussion

Our results suggest that a strategy of modular training in infection control practices that include individualized and supervised staff education can improve compliance in infection control practices and reduce HAI rates substantially in a tertiary hospital in a low-income country. The decrease in the device utilization ratio in the post-intervention period supports prior research showing that care of devices, early removal when feasible and adherence to aseptic precautions can reduce HAIs. The investments in the training program were modest, yet the overall reductions in cost of avoidance of HAIs were substantial. The return on investment for every dollar spent on training was large enough ($236 for every dollar invested) to make a powerful case for institution of standardized infection control training programs in many hospitals in the developing world.

Previous studies of specific training strategies for individual HAIs such as CLABSI have consistently demonstrated a substantial reduction in frequently used outcome measures [14, 15]. A reduction in HAIs’ incidence and costs was accomplished by focused surveillance using the combined infection control resources in coronary artery bypass surgery and gastric bypass surgery [16]. Significant reductions in VAP, CA-UTI, CLABSI were demonstrated in ICUs of four Mexican cities by effective skill-based training and education of direct health-care providers [11].

The Study of Efficacy of Nosocomial Infection Control has demonstrated that infection control programs are cost-effective. The cost of establishing the infection control team could be recovered by preventing just 7% of HAIs [17]. Other studies have also shown cost savings related to reduction in HAIs [18, 19].

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**Table 5** Overall and average cost savings (per case) for each HAIs (in USD)

<table>
<thead>
<tr>
<th></th>
<th>SSI</th>
<th>CLABSI</th>
<th>VAP</th>
<th>CA-UTI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct costa</td>
<td>$46,938 (1173)</td>
<td>$16,863 (843)</td>
<td>$21,737 (1358)</td>
<td>$50,505 (561)</td>
<td>$90,590 (1065)</td>
</tr>
<tr>
<td>Indirect costb</td>
<td>$19,778 (494)</td>
<td>$8,967 (448)</td>
<td>$9,020 (563)</td>
<td>$3,548 (394)</td>
<td>$41,315 (486)</td>
</tr>
<tr>
<td>Cost of excess LOSc</td>
<td>$54,222 (1355)</td>
<td>$22,000 (1100)</td>
<td>$29,333 (1833)</td>
<td>$34,000 (377)</td>
<td>$108,956 (1281)</td>
</tr>
<tr>
<td>Opportunity costd</td>
<td>$190,657 (2243)</td>
<td>$190,657 (2243)</td>
<td>$190,657 (2243)</td>
<td>$190,657 (2243)</td>
<td>$190,657 (2243)</td>
</tr>
<tr>
<td>Grand total</td>
<td>$431,518 (2176)</td>
<td>$431,518 (2176)</td>
<td>$431,518 (2176)</td>
<td>$431,518 (2176)</td>
<td>$431,518 (2176)</td>
</tr>
</tbody>
</table>

All costs are in US dollars.
Costs in parenthesis indicate average savings per infection averted.
Time period of cost savings is for a year in CVTS department.

aDirect cost includes cost of procedure, service charge, imaging, lab investigations and drugs.
bIndirect cost includes loss of job of patient, loss of job of bystander, stay and food for the bystanders.
cCost of excess length of stay (LOS) because of infection.
dOpportunity cost includes costs (to the hospital) of lost opportunity of admitting additional patients and performing additional procedures.
Our study is unique in examining the impact on clinical outcomes and costs of training instituted simultaneously for all four standard HAIs. In non-research clinical settings, infection control practice needs to be holistic and comprehensive. Packaging infection control practice training for different HAIs outcomes in a single training program has obvious efficiencies. Regular audits, continuous sharing of information with stakeholders and bedside teaching that promotes behavioral changes can be synergistic in contributing to improved patient outcomes and cost benefit. In our study, the return on investment was substantially higher than that was reported in other studies, perhaps because the costs of establishing a team were much lower. Additionally, we included indirect costs through follow-up for 30 days. Indirect costs are perhaps of even greater significance in the developing world because a significant number of daily wage earners’ livelihoods are dramatically affected by ill-health in any of the family members.

There are major changes in the health-care delivery patterns in most developing countries and emerging economies in recent decades, including exponential growth in sophisticated multispecialty hospitals that focus largely on tertiary services. Most of these facilities are concentrated in urban areas and largely run by private enterprise. As a result, the costs of health care have spiraled upward. Because of the very limited availability of health insurance, most health expenses are ‘out-of-pocket,’ and the resultant economic impact on individuals and their families is considerable. A large prospective international multicenter study of ICUs suggests that the incidence of individual HAIs may be 2 to 6 times higher in developing countries. Given this very large disease burden together with the peculiarities of health economics in the developing world, the impact of HAIs is likely to be substantial, and urgent measures to improve awareness and to institute structured infection control practices are warranted.

Training programs in infection control practices are easy to design and implement in a wide variety of clinical settings. The time required to set up the program is relatively short. It is also possible to ensure continuity by making standardized training material available to all stakeholders. The cost benefit of establishing a structured training and its impact on savings from reduction in HAIs is very encouraging. Post-intervention monitoring for longer duration and re-training will make the program more robust and strong.

Our study had some limitations. Implementation of the training program may not have accounted for all the improvements in standard outcomes of the four HAIs. Some of the reduction may have been the result of improving general awareness or other influences, and our study did not include a ‘control group,’ where the training program was not implemented.

Instituting control groups in low-income settings is logistically difficult as it can be in all quality improvement studies. The study also lacked long-term follow-up to establish whether the benefits of training were sustained over a longer period of time. This will require longitudinal follow-up at yearly intervals after completion of the training. Re-training may be an important component and should be included in the in-service schedule. A single-institution study may not be reproducible in other hospitals in the developing world. However, given the simplicity of the training modules and the structure of the infection control program, it should be feasible to test the impact in other institutions or in a multi-institutional study with customized modifications. Given the complexity of the health-care environment, cost estimates are, at best, approximations.

In conclusion, this study demonstrates that establishing a modular training and implementation of infection control practices can be done with a small investment in the limited resource environment. This translates into substantial reduction in the incidence of common HAIs and considerable savings through reductions in cost of avoidance.

Acknowledgements

The authors wish to acknowledge the assistance from Children’s Heartlink who facilitated the travel of Jeannie Pfeiffer, International expert in Infection Control from University of Minnesota.

Funding

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Conflict of interest

None declared.

References


