

Intravascular catheter bloodstream infections: an effective and sustained hospital-wide prevention program over 8 years

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Many commonly occurring health care-associated infections are life-threatening, especially bloodstream infections (BSIs).^{1,2} Intravascular (IV) catheters are the most frequent cause of BSIs, most of which are preventable.³⁻⁸

In the United States, BSIs are now the eighth leading cause of death,¹ and 250 000 episodes associated with central venous catheters (CVCs) are estimated to occur there annually.³ In Australia in the early 1990s, about 2% of all CVCs and 0.04% of peripheral venous catheters were associated with BSIs, resulting in over 3000 catheter-related BSI episodes per year and an average rate of 1.6 per 1000 admissions in Australian teaching hospitals.⁴ More recently in England, this rate was 2.3 per 1000 admissions in teaching hospitals and 0.9 per 1000 admissions in non-teaching hospitals.⁷ The reported mortality associated with BSIs is variable,³ but in the US even a low rate of attributable mortality of 10% translates to 25 000 deaths per year.

Ongoing surveillance of BSIs associated with IV catheters is patchy. Available "whole of hospital" data show that IV catheters account for 30% or more of BSIs in Australia, England and the US.^{5-7,9} Data collection and surveillance of BSIs has been recommended, but primarily for intensive care units (ICUs),^{10,11} even though most CVCs are used outside ICUs.¹²

To prevent the occurrence of BSIs and improve management practices, we implemented a hospital-wide surveillance and intervention program.

METHODS

Canberra Hospital is a 500-bed tertiary referral hospital offering most medical and surgical services for a population of over 550 000. In 1990, the hospital's rate of IV catheter-related BSIs was 1.7 per 1000 discharges.⁴

We used a quality assurance grant to employ a full-time nurse and a part-time data entry clerk (0.2 full-time equivalent [FTE]), and to purchase computer hardware and software. A part-time nurse (0.6 FTE) was employed once the program was established (total recurrent costs per annum of about A\$60 000). Our surveillance study ran for 8 years, from 1998 to 2005.

ABSTRACT

Objective: To evaluate a hospital-wide surveillance and intervention program introduced to reduce the incidence of bloodstream infections (BSIs) caused by intravascular (IV) catheters.

Design, setting and participants: Prospective surveillance of all inpatients and outpatient attendees with positive blood cultures (both hospital-onset and community-onset) at a 500-bed tertiary referral hospital from 1998 to 2005.

Interventions: Prompt review of all positive blood cultures with identification of BSIs due to IV catheters and associated preventable factors; weekly team meetings and regular reports to clinical areas, with assistance to implement targeted interventions.

Main outcome measure: Number of BSI episodes due to IV catheters per year.

Results: There were 491 BSI episodes due to IV catheters, mainly central venous catheters. Episodes per year fell from 110 in 1998 to 48 in 2005 (from 32% of all BSI episodes to 14%; a > 50% reduction). From 1998 to 2005, the rate per 1000 discharges fell from 2.3 to 0.9 (*P* for trend < 0.0005) and the rate per 1000 patient-days fell from 0.6 to 0.3 (*P* for trend < 0.0005).

Conclusions: Our program was associated with a profound drop in the number of IV catheter-related BSIs per year. Active surveillance and intervention programs can lead to substantial and sustained reductions in these common life-threatening infections.

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The project nurse visited the microbiology laboratory daily to review all BSI episodes (both hospital- and community-onset) after receiving notification of positive blood cultures. The nurse also visited wards to obtain episode details from the patient, the caring medical and nursing staff, and medical records. Episodes were categorised using national definitions.¹³ IV catheter-related BSIs and primary health care-associated bacteraemias were categorised using US Centers for Disease Control and Prevention definitions.³ At Day 7 or earlier if discharged, the patient's outcome (alive or not) and the contribution of sepsis to mortality or ongoing morbidity were assessed.

A multidisciplinary team reviewed the clinical details of all new positive blood culture results at a 30-minute weekly meeting. Particular attention was paid to any episode potentially associated with IV catheter sepsis or preventable causes.

Data were obtained from the hospital's financial and activity reports for occupied bed-days (here referred to as "patient-days") and separations ("discharges") and included day-only patients. Trends in the annual rate of BSIs per patient-days and discharges were estimated by aggregating data for BSIs, patient-days and discharges for each calendar

year. Rates were modelled in Stata (Stata-Corp, College Station, Tex, USA) using log linear regression of the number of BSIs, with the logarithm of the number of patient-days or discharges as the offset term. Year was fitted as a linear term to assess whether there was a trend, but without modelling the trend itself. Significance of the regression term was assessed using a likelihood ratio test at the 5% level. Rate ratios for 2005 versus 1998 were calculated using the fitted values for the number of BSIs.

This study was a quality assurance program but was also approved by the ACT Health Human Research Ethics Committee.

RESULTS

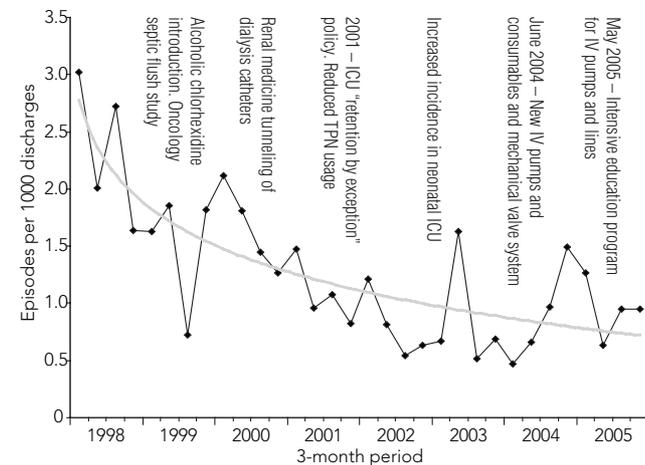
Over the 8-year period, there were 491 BSI episodes caused by IV catheters, with a greater than 50% reduction during the study, from 110 episodes in 1998 to 48 in 2005 (Box 1, Box 2). From 1998 to 2005, the rate of IV catheter-related episodes fell from 2.3 to 0.9 per 1000 discharges (*P* for trend < 0.0005), and from 0.6 to 0.3 per 1000 patient-days (*P* for trend < 0.0005). The rate ratio was 0.35 (95% CI, 0.26-0.46) for discharges and 0.36 (95% CI, 0.27-0.48) for patient-days.

1 Number of bloodstream infection episodes associated with each intravascular (IV) device type, by year

IV device type	1998	1999	2000	2001	2002	2003	2004	2005	Total
CVC	50	35	25	17	19	14	11	15	186
Hickman	25	7	14	16	1	2	5	5	75
Vascath	18	6	15	10	7	5	4	5	70
SPV	6	3	7	2	3	1	7	7	36
Umbilical	3	3	2	1	3	8	4	3	27
Gortex loop	2	9	5	1	1	0	2	2	22
Longline	2	1	8	0	2	2	2	1	18
Portacath	1	7	1	2	0	2	4	3	20
PICC	0	0	2	5	1	11	3	6	28
Other*	3	1	2	0	2	0	0	1	9
Total	110	72	81	54	39	45	42	48	491

* Arterial catheters, 3; arteriovenous fistula, 2; temporary pacemakers, 2; Swan-Ganz catheter, 1; femoral sheath, 1. CVC = central venous catheter. SPV = short peripheral venous. PICC = peripherally inserted central catheter. ◆

2 Rate of intravascular (IV) device-related bloodstream infection episodes per 1000 discharges, 1998–2005*



Trendline data: $y = -0.5946\ln(x) + 2.7805$. * In 1990, the rate was 1.7/1000 discharges.⁴ ICU = intensive care unit. TPN = total parenteral nutrition. ◆

Although the number of episodes in each 3-month period fluctuated, there was an overall downward trend from the beginning to the end of the project (Box 2). Episodes of IV catheter sepsis resulted in 4% mortality (20/491 episodes) by Day 7. A subgroup of 44 patients with IV catheter sepsis in 2000–2001 was followed for 6 months, and had a cumulative mortality of 4% at Day 7, 12% at 1 month, and 39% at 6 months.

CVCs were the most common IV catheters associated with BSIs (Box 1). However, all catheter types were implicated, including short peripheral catheters and peripherally inserted central catheters (PICC lines).

IV catheter sepsis occurred in all areas of the hospital (Box 3), but the numbers in each unit varied from year to year. In 2004, there were 1238 CVCs, 617 PICC lines and 27 683 peripheral catheters purchased, with BSI rates of 8.8 per 1000 CVC catheters (0.9%), 4.9 per 1000 PICC lines (0.5%), and 0.25 per 1000 peripheral catheters (0.03%).

Staphylococcus aureus (methicillin-sensitive and methicillin-resistant) was the most common organism involved in IV sepsis, followed by coagulase-negative staphylococci and *Candida* spp. (Box 4). Comparing 1998–2001 with 2002–2005, the largest percentage falls were with *S. aureus*, coagulase-negative staphylococci, and gram-negative rods.

In 1998, IV catheters were the most common primary site for sepsis when all BSI episodes from any cause were examined, accounting for 110 of the 339 significant episodes (32%) (Box 5). After 2002, IV catheters were no longer the commonest cause of

BSIs; by 2005 they had decreased to be the third most common primary site (48/341 episodes; 14%) after gastrointestinal tract and genitourinary tract episodes. Primary health care-related episodes (ie, all IV and all “unknown” primary site BSIs) dropped from 128 episodes in 1998 to 87 in 2005 (Box 5). In 2005, this was a rate of 1.7 per 1000 discharges; down 38% from 1998.

DISCUSSION

The decline in IV catheter-related BSIs was associated with multiple interventions. Individual units instigated many of these, usually in consultation with the infection control service after receiving feedback and advice about their rates and numbers of IV-related BSIs (Box 6). We believe our surveillance program was the catalyst for many of these interventions, which may otherwise have been introduced later or not at all.

The project nurse's ward visits to discuss each BSI episode with the medical and nursing staff provided prompt feedback. This interaction and the collection and feedback of other data allowed the units to “buy in” to the problem. We believe the combined interaction of all these program elements resulted in the dramatic reduction in sepsis observed; a point also made by others.¹⁰ Reliable and regular reporting of results also sustained enthusiasm for ongoing vigilance.

Passive surveillance based on medical and laboratory records alone is unlikely to have achieved the same positive outcomes. With its associated time lag, passive surveillance is

3 Number of intravascular catheter-related bloodstream infection episodes over time, by hospital unit

Hospital unit/ department	1998– 1999	2004– 2005	1998– 2005
Obstetrics/ gynaecology	0	0	1
General surgery	13	7	29
Paediatric surgery/ medical	7	7	29
Adult ICU	16	2	31
Surgical services (other)	8	9	32
Gastroenterology*	7	12	38
Medical oncology	26	3	44
Neonatal ICU	10	11	51
Medical services (other)	20	13	58
Renal	32	10	75
Haematology	43	16	103
Total	182	90	491

* Frequently associated with total parenteral nutrition. ICU = intensive care unit. ◆

also likely to have been much less accurate in identifying the primary sites for sepsis or patient outcome. Studies in ICUs in the US, Germany, Brazil, Australia and Switzerland have shown that active surveillance and interventions can substantially reduce the number of BSIs caused by IV catheters.^{8,10,11,14–18} Our study confirms the findings of Meier et al¹⁹ that this can also be done for the whole hospital.

4 Number of microorganisms causing intravascular catheter-related bloodstream infection episodes, by year

Microorganism*	1998	1999	2000	2001	2002	2003	2004	2005	Total (%)
<i>Staphylococcus aureus</i>	26	30	29	20	20	14	13	13	165 (31%)
Methicillin-sensitive	24	25	19	16	14	11	11	10	130 (25%)
Methicillin-resistant	2	5	10	4	6	3	2	3	35 (7%)
Coagulase-negative staphylococci	42	14	24	9	8	22	8	11	138 (26%)
<i>Candida</i> spp.	8	1	4	4	1	0	8	8	34 (6%)
<i>Klebsiella</i> spp.	7	3	6	7	1	3	1	3	31 (6%)
<i>Stenotrophomonas maltophilia</i>	6	8	2	3	0	1	2	1	23 (4%)
<i>Enterobacter</i> spp.	4	2	5	4	1	1	2	0	19 (4%)
<i>Escherichia coli</i>	2	2	1	1	2	0	4	0	12 (2%)
<i>Pseudomonas</i> spp.	4	3	3	3	2	0	2	4	21 (4%)
Other†	17	14	11	6	7	7	10	12	84 (16%)
Total	116	77	85	57	42	48	50	52	527 (100%)

* In 31 episodes, there was more than one significant organism isolated. † The most common "other" isolates were: *Viridans streptococci*, 12; *Acinetobacter* spp., 10; *Proteus* spp., 10; *Enterococcus* spp., 10; *Serratia* spp., 8; and *Corynebacterium jeikeium*, 4. ◆

5 Rates of intravascular (IV) catheter sepsis and hospital admission details, by year

	1998	1999	2000	2001	2002	2003	2004	2005
Total significant episodes*	339	308	318	289	272	316	354	341
Total indeterminate episodes	35	37	37	36	31	32	25	35
Total contaminant episodes	245	200	197	197	217	210	235	266
Total positive blood cultures	619	545	552	522	520	558	614	642
IV catheter-related episodes	110	72	81	54	39	45	42	48
Health care-related primary bacteraemia	128	111	106	92	73	75	71	87
Total significant episodes excluding IV catheters	228	235	239	234	232	271	312	291
Discharges	46 656	47 454	49 090	49 606	49 400	50 805	48 655	51 122
Rate per 1000 discharges of:								
Total significant episodes	7.2	6.5	6.5	5.8	5.5	6.2	7.2	6.6
Total significant episodes excluding IV catheters	4.9	5.0	4.9	4.7	4.7	5.3	6.4	5.7
IV-related episodes†	2.3	1.5	1.7	1.1	0.8	0.9	0.9	0.9
Patient-days‡	171 455	164 027	166 537	170 285	170 661	173 833	171 173	177 239
Rate per 1000 patient-days of:								
Total significant episodes	2.0	1.9	1.9	1.7	1.6	1.8	2.1	1.9
Total significant episodes excluding IV catheters	1.3	1.4	1.4	1.4	1.4	1.6	1.8	1.6
IV-related episodes	0.6	0.4	0.5	0.3	0.2	0.3	0.2	0.3

* Includes all bloodstream infection episodes treated and diagnosed at the hospital (ie, all community- and hospital-onset from all causes). † In 1990, the rate was 1.7/1000 discharges. ‡ Includes day-only patients. ◆

There are now at least 60 fewer BSI episodes occurring per year in our hospital than when the program started. This is likely to represent a saving of six or more lives per year (assuming at least 10% attributable mortality). Each IV catheter-related BSI episode also has significant financial costs. Measuring these is beyond the scope of this study, but a

South Australian study found that each case of *S. aureus* bacteraemia may be associated with additional health care costs of about A\$20 000.²⁰ In the US, the attributable cost of each CVC-associated BSI episode (from all organisms) is estimated at US\$34 508–\$56 000.³ Using the most conservative of these estimates, if 60 bacteraemia cases are

prevented each year, and at least 15 of these are due to *S. aureus*, then annual hospital cost savings will be at least A\$300 000. However, a more realistic estimate is over a million dollars per year. This is offset by the net additional cost of the program (about A\$60 000 per year).

Our rate per 1000 patient-days for primary nosocomial BSIs fell 34% from 0.8 in 1998 to 0.5 in 2005. A study in a 200-bed hospital in Iowa found a similar decrease in primary BSIs (35%) after the introduction of an 11-member IV team (from 1.1 to 0.7 per 1000 patient-days).¹⁹ We were able to sustain a large reduction in IV-related sepsis, over a longer study period and at a much lower cost than with a full IV team.

Our data show the value of an ongoing surveillance program. On several occasions during the study we saw rising rates and then "peaks" in sepsis (Box 2). One was in 2003 in the neonatal ICU and prompted a complete review of their IV catheter-related procedures. We never determined the cause of this increase, but believe its early detection, in conjunction with the staff reviewing protocols and enacting changes, resulted in its resolution. The same benefit was noted with another peak in 2004 after the introduction of a new mechanical valve needleless IV system and new mechanical pumps. Similar increases of IV sepsis with use of these systems have been reported in the US.²¹ After an extensive education program at our hospital, IV sepsis rates returned to lower levels.

Programs that use only denominators such as "catheter line-days" and focus on ICUs are inappropriate. Whole-of-hospital programs should be implemented to capture all BSI episodes, with denominators that are easier to collect (eg, episodes per 1000 discharges or patient-days).^{7,8} Sepsis rates expressed only as catheter line-days do not acknowledge timely removal of lines and thus removal of risk,¹⁴ and may lead to continued overuse of these catheters and help to hide the numbers of episodes that occur.

The initial rate of IV sepsis in our hospital was reasonably low by most Australian⁴ and international comparisons.³ Our ICU rates were lower than those reported for comparable units in New South Wales (1.8 v 3.7 per 1000 line-days)^{14,22} and than the average ICU rate in the US (5.3 per 1000 line-days for CVCs).³ Our study shows that a surveillance and intervention program can decrease BSI episodes even in hospitals with relatively low rates of sepsis. We believe that over 75% of episodes that still occur are due to preventable factors. Thus, the baseline number of "unavoidable" BSIs due to IV catheters should

6 Interventions for intravascular (IV) catheter-related bloodstream infections (BSIs)

Intervention	Hospital units
Prospective surveillance of BSIs	Hospital-wide
Subcutaneous tunnelling of Vascath catheters	Renal medicine
Central venous catheter (CVC) "retention by exception"	Intensive care unit (ICU)
Prevention of septic flush by correct use of alcohol antiseptics	Oncology, haematology
Monitoring of peripheral IV policy compliance	Aged care, general surgery
Patient information pamphlet for CVC care	Hospital-wide, community
Introduction of alcoholic chlorhexidine skin prep for IV insertions	Hospital-wide
Reduction in the use of total parenteral nutrition	Hospital-wide
Notification of each IV catheter-related BSI to specialist in charge of patient by letter outlining current hospital policies and pointing out potential breaches in the episode	Hospital-wide, medical officer
Extensive education after introduction of new infusion pumps and consumables	Hospital-wide, general practitioners
Dissemination of BSI project information	Hospital-wide, GPs, media

* The CVC was routinely removed when the patient left the ICU unless a specific and appropriate reason could be identified and documented to justify its continued retention (see references^{14,15} for more details). ♦

be only about 15 episodes per year, or 0.2 per 1000 discharges.

A similar approach can be put into place in most hospitals. Our surveillance and intervention program is relatively inexpensive and likely to be extremely cost-effective. Programs such as this should result in a major reduction in IV catheter-related sepsis.

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COMPETING INTERESTS

Travel assistance was received from Becton Dickinson Pty Ltd (supplier of IV infusion equipment) for Di Dreimanis to attend an international conference in July 2006, and for Jan Roberts and Wendy Beckingham to attend an interstate meeting in 2005.

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