Title
Cost savings of universal decolonization to prevent intensive care unit infection: implications of the REDUCE MRSA trial.

Permalink
https://escholarship.org/uc/item/43g0531q

Journal
Infection control and hospital epidemiology, 35 Suppl 3(S3)

ISSN
0899-823X

Authors
Huang, Susan S
Septimus, Edward
Avery, Taliser R
et al.

Publication Date
2014-10-01

DOI
10.1086/677819

Peer reviewed

Cost Savings of Universal Decolonization to Prevent Intensive Care Unit Infection: Implications of the REDUCE MRSA Trial

Susan S. Huang, MD, MPH;[1] Edward Septimus, MD;[2] Taliser R. Avery, MPH;[3] Grace M. Lee, MD, MPH;[3] Jason Hickok, MBA, RN;[4] Robert A. Weinstein, MD;[5] Julia Moody, MS;[4] Mary K. Hayden, MD;[6] Jonathan B. Perlin, MD, PhD;[4] Richard Platt, MD, MS;[3] G. Thomas Ray, MBA7

OBJECTIVE.   To estimate and compare the impact on healthcare costs of 3 alternative strategies for reducing bloodstream infections in the intensive care unit (ICU): methicillin-resistant *Staphylococcus aureus* (MRSA) nares screening and isolation, targeted decolonization (ie, screening, isolation, and decolonization of MRSA carriers or infections), and universal decolonization (ie, no screening and decolonization of all ICU patients).

DESIGN.   Cost analysis using decision modeling.

METHODS. We developed a decision-analysis model to estimate the health care costs of targeted decolonization and universal decolonization strategies compared with a strategy of MRSA nares screening and isolation. Effectiveness estimates were derived from a recent randomized trial of the 3 strategies, and cost estimates were derived from the literature.

RESULTS. *In* the base case, universal decolonization was the dominant strategy and was estimated to have both lower intervention costs and lower total ICU costs than either screening and isolation or targeted decolonization. Compared with screening and isolation, universal decolonization was estimated to save $171,000 and prevent 9 additional bloodstream infections for every 1,000 ICU admissions. The dominance of universal decolonization persisted under a wide range of cost and effectiveness assumptions.

CONCLUSIONS. A strategy of universal decolonization for patients admitted to the ICU would both reduce bloodstream infections and likely reduce healthcare costs compared with strategies of MRSA nares screening and isolation or screening and isolation coupled with targeted decolonization.

The intensive care unit (ICU) has been a long-standing focus of attention for reducing largely preventable healthcare- associated infections.[1, 3] Many prevention strategies have emerged to reduce the prevalence or transmission of anti-biotic-resistant pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), as well as to reduce bloodstream infections (BSis). [4• 7] Several of these strategies have evidence of benefit in observational studies, but comparative effectiveness studies have only recently been published, and comparative cost analyses are lacking.[8• 11]

Recently, 3 promising strategies were compared in a large, cluster-randomized trial (the Randomized Evaluation of De- colonization versus Universal Clearance to Eliminate [REDUCE] MRSA trial).[9] This 43-hospital, 74-ICU trial com- pared the effectiveness of screening and isolation, targeted decolonization, and universal decolonization with respect to their ability to reduce the rate of MRSA-positive clinical cultures and all-pathogen BSis in adults. "Screening and isolation" was the routine and long-standing strategy in these hospitals and consisted of screening all patients for MRSA nasal colonization at admission to the ICU and using contact precautions for patients with current or previous MRSA colonization or infection.[1 2] One-third of hospitals were randomized to initiate "targeted decolonization," which involved screening and isolation but added a 5-day decolonization regimen for all known MRSA carriers or patients with MRSA infection that consisted of twice-daily intranasal mupirocin and daily bathing with chlorhexidine-impregnated cloths. Another third of hospitals were randomized to initiate "universal decolonization," in which ICU admission screening for MRSA was stopped, contact precautions were unchanged from the other strategies, and all patients received twice-daily intra- nasal mupirocin for 5 days plus daily bathing with chlorhexidine-impregnated cloths for the entire ICU stay.

The results of the REDUCE MRSA trial indicated that universal decolonization was more effective than targeted de- colonization or screening and isolation in reducing BSis from any

pathogen. However, the cost implications of these strategies have not been addressed in light of these results. Our objective was to estimate the incremental effect on healthcare costs associated with targeted decolonization and universal decolonization compared with screening and isolation, which we considered to be the current standard of care. If either of these 2 strategies were found to be less costly than screening and isolation, the benefits of implementing one of these strategies would be to not only improve health but also decrease use of healthcare resources.

METHODS

Decision Analysis Model

We developed a static decision analysis model, programmed in Microsoft Excel, that compared the effects of the above 3 strategies for preventing infections in adult ICUs: (1) screening and isolation, (2) targeted decolonization, and (3) universal decolonization (Table 1).[9]

Using data from the REDUCE MRSA trial and cost and utilization estimates from published sources, we simulated the effects of each of the 3 strategies on healthcare costs, ICU days, and BSis for 1 year, assuming a hospital with 1,000 annual ICU admissions. Because the trial did not measure effects outside of the ICU, we only modeled ICU impact. The primary perspective was that of the healthcare system. Be- cause this was strictly a cost analysis, no quality-of-life measures were incorporated, nor were health states assigned dollar values.

Model Inputs: Percentage of Patients Placed on Contact Precautions

We assumed that the background percentage of patients who arrive at the ICU and have test results positive for MRSA or have a known recent history of MRSA infection or colonization was 11% (Table 2). This estimate was based on the ICU MRSA importation rate reported from the baseline period in all arms of the REDUCE MRSA trial,[9] and it remained unchanged during the implementation phase for the arms that continued screening. For the universal decolonization arm, knowledge of MRSA importation decreased in the implementation phase to 4%, likely because of cessation of screening and possibly because of effects of decolonization for patients readmitted to the ICU. Therefore, under the universal decolonization strategy, fewer persons were modeled as being placed on contact precautions. For this cost analysis, it was not necessary to model the "true" percentage of patients colonized with MRSA or the relationship between MRSA colonization and the rate of BSI. The percentage of patients with test results positive for MRSA is primarily important in the model because it affects the number of persons who are placed on contact precautions and therefore affects costs. For the universal colonization strategy, 4% of patients were placed on contact precautions (and therefore incurred the associated costs) because they had some known history of MRSA colonization or infection, but this percentage should not be interpreted as directly relating to any "true" colonization rate.

Model Inputs: Risk of BSI

Using data from the REDUCE MRSA trial, the baseline incidence of BSI was assumed to be 19.63 cases per 1,000 ICU admissions, equivalent to approximately 5 infections per 1,000 ICU-days (Table 2). The risk of BSI under the 3 different strategies was also derived from the REDUCE MRSA trial, which reported as-assigned adjusted hazard ratios of 0.98, 0.77, and 0.55 for the screening and isolation, targeted de- colonization, and universal decolonization strategies, respectively[9]. These results were relative to the pre-trial time period, in which all arms were

performing screening and isolation. To compare the targeted decolonization and universal decolonization strategies to screening and isolation, we adjusted the results of those strategies so as to be relative to the long-standing gold standard of screening and isolation.[11] This resulted in the relative risk of BSI being 1.00, 0.7857, and 0.5612 for the screening and isolation, targeted decolonization, and universal decolonization strategies, respectively.

TABLE 1. Description of the Strategies to Prevent Intensive Care Unit (ICU) Bloodstream Infection Considered in the Cost Analysis

Strategy	Description
Screening and isolation baseline strategy	Universal nares screening for MRSA carriage at ICU admission; use of contact precautions For MRSA carriers (by history or positive screening test result/clinical culture)
Targeted decolonization	Universal nares screening for MRSA carriage at ICU admission; use of contact precautions for MRSA carriers (by history or positive screening test result/clinical culture); decolonize MRSA carriers with daily chlorhexidine baths and mupirocin treatment
Universal decolonization	No screening for MRSA at admission to the ICU; use of contact precautions for MRSA carriers (by history or positive clinical culture); give daily chlorhexidine baths and mupirocin to all patients in ICU

NOTE. MRSA, methicillin-resistant *Staphylococcus aureus.*

TABLE 2. Decision-Analysis Model Inputs Derived from the REDUCE MRSA Trial: MRSA Colonization and Risk of Bloodstream Infection by Intensive Care Unit (ICU) Strategy

Input parameter	Base case	Range
Patients arriving at ICU who test positive for MRSA colonization or who have known MRSA history, by ICU strategy		
Screening and isolation•	11	5-20
Targeted decolonization'	11	5-20
Universal decolonization [6]	4	4-20
Baseline risk of bloodstream infection (screening and isolation strategy) per 1,000 ICU admissions	19.63'	5-30
Risk of any bloodstream infection, by strategy, relative to screening and isolationJ		
Screening and isolation	1.0000	
Targeted decolonization	0.7857	0.6657-0.9157
Universal decolonization	0.5612	0.4912-0.6512

NOTE. Data are percentage of patients, unless otherwise indicated. MRSA, methicillin-resistant *Staphylococcus aureus;* REDUCE, Randomized Evaluation of Decolonization versus Universal Clearance to Eliminate. All estimates derived from Huang et al.[9]

" Estimate based on the average baseline values reported by Huang et al.[9]

" Estimate based on the trial results reported by Huang et al.[9] This differs from the other strategies, because under the universal decolonization strategy, ICU screening was stopped and active decolonization was occurring for all patients. As the intervention progressed, patients who were readmitted may have been less likely to be identified as MRSA positive. Patients with an earlier ICU admission would be less likely to be screened for MRSA and less likely to acquire MRSA because of universal decolonization. In the trial, 47% of patients with a history of MRSA had a previous admission in the past year. The fact that this 4% value is lower than for the other 2 strategies does not imply anything about the "real" colonization rate. The only impact of this value on the cost results is that it means fewer persons are put on contact precautions under the strategy of universal decolonization.

'Equivalent to 4.99 bloodstream infections per 1,000 ICU-days.

dIn the published report of the trial,[9] the effectiveness of the strategies was reported relative to the baseline (preintervention) period. We have here adjusted those results so as to make the screening and isolation strategy the reference. "Low" and "high" represent 95% confidence intervals.

Model Inputs: Costs and ICU-Days

Parameter estimates related to the base case are shown **in** Table 3. Intervention costs were derived from the literature. Intervention-related costs are the costs of screening, contact precautions, and decolonization. Where possible, preference was given to estimates that were more recent and were from the United States. The estimates used in most of the recent literature did not vary substantially, with the exception of the cost of an MRSA screening test and the cost of mupirocin. Variation in

screening costs were primarily related to whether the screening was assumed to be performed using the more costly polymerase chain reaction (PCR) test or the less costly chromogenic agar culture. Variation in literature estimates of the cost of mupirocin primarily related to whether generic or trade mupirocin was assumed to be used. In our base case, we assumed the chromogenic agar culture was used for screening (as it was in nearly all hospitals of the REDUCE MRSA trial) and that generic mupirocin was used for de- colonization. We also assumed that positive chromogenic agar cultures would not require confirmatory tests, and therefore we assumed no difference in screening costs between positive and negative screens. Any additional labor costs involved in applying mupirocin were assumed to be negligible, and be- cause patients are typically bathed at least once a day as part of usual care, we assumed that the cost of bathing with chlorhexidine cloths does not require any additional labor. Cost estimates reflect the "steady state;" we did not attempt to estimate start-up costs, such as those that might be associated with training staff. All cost estimates are in $US, adjusted to year 2012 using the consumer price index.

We used estimates from the literature to estimate the incremental hospital days and cost of a BSI (and therefore the incremental savings associated with preventing an infection). Hassan et al1 [3] estimated that the incremental hospital-days associated with a hospital-acquired infection (not specifically BSI) was 3.296. In addition, they estimated that the cost of an additional hospital-day once an infection was acquired was 24% higher than the cost of an uninfected day. Dasta et al[[6] estimated that the mean cost of an ICU-day (after day 3) was $4,385 (after adjusting to 2012 dollars). Applying the above estimates, we estimated the incremental cost of a BSI to be $17,920 (3.296 x [4,385 + (0.24 x 4,385)]). This estimate is consistent with the estimated incremental cost of BSis reported by Kilgore et al2[5] ($22,371 in year 2012 dollars), who, like Hassan et al13, used a large US database and implemented methods to control for heterogeneity and endogeneity biases. All differences among the 3 strategies in hospital days and general ICU costs (not including intervention costs) were assumed to be due entirely to differences in the incidence of BSis and their effects on length of stay and cost per day.

To test the sensitivity of the model results, we varied several important parameters (baseline incidence of BSI, reduction in BSI associated with universal decolonization, and incremental ICU cost of BSI) over a wide range. In addition, we estimated the differences between the 3 screening strategies under a number of alternative scenarios to the base case. For example, we included a scenario in which the PCR test, rather than chromogenic culture, is used to test for MRSA, and a scenario in which trade, rather than generic, mupirocin is used for decolonization. Another scenario included only those costs estimated to be variable in the short run. In their study of variable versus fixed costs of hospital care, Roberts et al'4 treated labor and overhead as fixed in the short run and estimated that only 16% of all hospital costs (corresponding to healthcare worker supplies) were avoidable in the short run. Therefore, in this scenario, we assumed that the incremental cost of a BSI was 16% of our base case estimate, and we assumed no incremental cost for labor to don and doff gowns and gloves.

Input parameter	Base case	Range for sensitivity analyses	Sources for base case, range
Cost of screening test ($)	9.12	9.12- 48.24	Fee schedule, fee schedule'
Contact precautions			
Cost per gown ($)	0.96		Kang et al"
Cost per pair of gloves ($)	0.09		Kang et al"
Time to don and doff gown and gloves (minutes)	1.00	1.00- 2.00	Kang et al" ; Puzniak et al"
No. of nurse visits per ICU patient-day"	53.00	30- 53	Kang et al[21]; Morgan et al'"
No. of physician visits per ICU patient-day"	13.00	6- 13	Kang et al[21]; Morgan et al"
Hourly wage, nurses	34.24		Kang et al"
Hourly wage, physicians	89.46		Kang et al[21]
Total cost per day of contact precautions	I 18.84		Calculated
Decolonization			
Cost of chlorhexidine impregnated cloths, 1 body wash ($)	5.35		Nelson et al"
No. of daily baths with chlorhexidine cloths'	1.25		Assumption
Cost of twice-daily intranasal mupirocin for 5 days ($)d	7.32	7.32- 93.92	Courville[24]
Incremental labor costs associated with decolonization '	0.00		Assumption
ICU-days			
Mean ICU-days for patients with negative MRSA screen without bloodstream infection'	4.15		Trial data
Mean ICU-days for patients with positive MRSA screen without bloodstream infection'	5.15		Trial data
Incremental ICU-days for persons with bloodstream infection, but due to additional comorbidities rather than infection per se'	3.46		Hassan et al"
Mean incremental ICU-days due to bloodstream infection'	3.30		Hassan et al"
Cost per ICU-day, days without bloodstream infection ($)"	4,385		Dasta et al"
Incremental cost per ICU-day for patients with bloodstream infection ($)'	1,052		Hassan et al"; Dasta et al"'
Total incremental cost of bloodstream infection ($)'	17,920	2,880-35,000	Calculated; Roberts et al"; Kilgore and Brossette25

NOTE. All costs are in $US and have been adjusted to the 2012 price level using the consumer price index. ICU, intensive care unit; PCR, polymerase chain reaction.

" Base case assumes screening culture using chromogenic agar, assuming no extra cost for a positive result. High-range cost assumes use of PCR screening test. Cost estimates are national limit reimbursement from 2013 US clinical diagnostic laboratory fee schedule, available at http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/ClinicalLabFeeSched/clinlab,html, HCPCS 87081, "Culture screen only," and HCPCS 87641 "Mr-staph dna amp probe." "Base case visit counts were based on direct observation of staff at 3 Department of Veterans Affairs hospitals and 1 university teach hospital." The actual observed mean physician visits per ICU-day was 17, but it was estimated that approximately 25% of these visits were associated with the teaching function of the hospitals (Daniel Morgan, personal communication). We therefore assumed 13 mean physician visits per day.

' Assuming 1 bath per day as routine, plus 0.25 baths per day to account for large patients, incontinence, and wastage.

" Base case assumes use of generic mupirocin. High value is based on authors' analysis of average wholesale price for trade mupirocin.

' Assume negligible additional labor time for applying mupirocin and that use of chlorhexidine cloths requires no additional time relative to normal bath. 'Estimates are from unpublished data from the Randomized Evaluation of Decolonization versus Universal Clearance to Eliminate [REDUCE] MRSA trial.' These lengths of stay were applied to the screening and isolation and targeted decolonization strategies. For universal decolonization, in which patients are not screened for MRSA colonization, the length of stays were calibrated so as to be the same as stays in the other 2 strategies, except for any reductions caused by prevention of bloodstream infections.

' Estimates reported in Hassan et al[13] were for all hospital-acquired infections and all units. We assumed these would apply to bloodstream infections that occurred in the ICU and that the additional hospital-days would be in the ICU.

" Because we use this estimate for the incremental costs of additional days within a stay, we used the mean cost as reported by Dasta et al"' for days 3 and later. The mean cost per ICU-day reported by Dasta et al[16] was not specifically for uninfected days. However, given the relatively low incidence of hospital-acquired infections (about 6% as reported in Hassan et al"), we treated this as a reasonable estimate for the cost of an uninfected ICU-day.

' Percentage increase (24%) in uninfected cost per day as estimated by Hassan et al" applied to estimated cost per ICU-day of Dasta et al.'"

' The low value of $2,880 is 16% of the base case estimate and is an estimate of short-run marginal costs that includes only healthcare worker supplies.

	Strategy		
Variable	Baseline screening and isolation	Targeted decolonization	Universal decolonization
ICU admissions			
Total admissions to ICU	1,000	1,000	1,000
No. of patients screened for MRSA at admission	1,000	1,000	0
No. of patients screening positive for MRSA (or status is otherwise known at admission)	110	110	40
No. of patients on contact precautions	110	110	40
No. of patients decolonized	0	110	1,000
No. of patients with any bloodstream infection	20	15	**11**
ICU-days			
Total no. of ICU-days	4,391	4,377	4,362
No. of patient-days with contact precautions	581	579	209
Costs ($)			
Cost of MRSA screening tests	9,120	9,120	0
Cost of contact precautions	69,010	68,830	24,890
Cost of decolonization	0	4,679	36,500
ICU costs, not including screening, contact precautions and decolonization	19,320,000	19,250,000	19,170,000
Total cost	19,400,000	19,330,000	19,230,000
Total cost per admission	19,400	19,330	19,230
Incremental costs (savings) per admission compared with screening and isolation ($)			
Intervention costs only (screening, contact precautions, decolonization)		4	(17)
Bloodstream infection-related ICU costs		(75)	(155)
All costs		(71)	(171)
Incremental costs (savings) per admission compared with screening and isolation ($)			
Intervention costs only (screening, contact precautions, decolonization)			(21)
Bloodstream infection-related ICU costs			(79)
All costs			(100)

NOTE. MRSA, methicillin-resistant *Staphylococcus aureus*.

RESULTS

Over the course of 1 year at a hospital with 1,000 annual adult ICU admissions, we estimated that a strategy of universal decolonization would prevent 9 BSis compared with a strategy of screening and isolation (11 vs 20) and 4 BSis compared with a strategy of targeted decolonization (11 vs15; Table 4). The universal decolonization strategy was estimated to have the lowest mean intervention costs, saving $17 per admission compared with screening and isolation and saving $21 per admission compared with targeted decolonization. By preventing BSis, the universal decolonization strategy was estimated to save $155 per admission in non-intervention, ICU-related costs compared with targeted de- colonization. In total, for every ICU admission, universal decolonization was estimated to save $171 compared with screening and isolation and $100 compared with targeted decolonization.

These results were robust to changes in the parameter estimates that were derived from the REDUCE MRSA trial.[9] Figure 1A shows the estimated savings per admission (com- pared with screening and isolation) of universal decolonization, assuming it was less effective at preventing BSis than was reported in the REDUCE MRSA trial. Because the strategy

A

Base case=0 .56

Relative risk ratio universal decolonization vs. Screening and Isolation

B

Baseline incidence of bloodstream infections per 1000 ICU admits

C

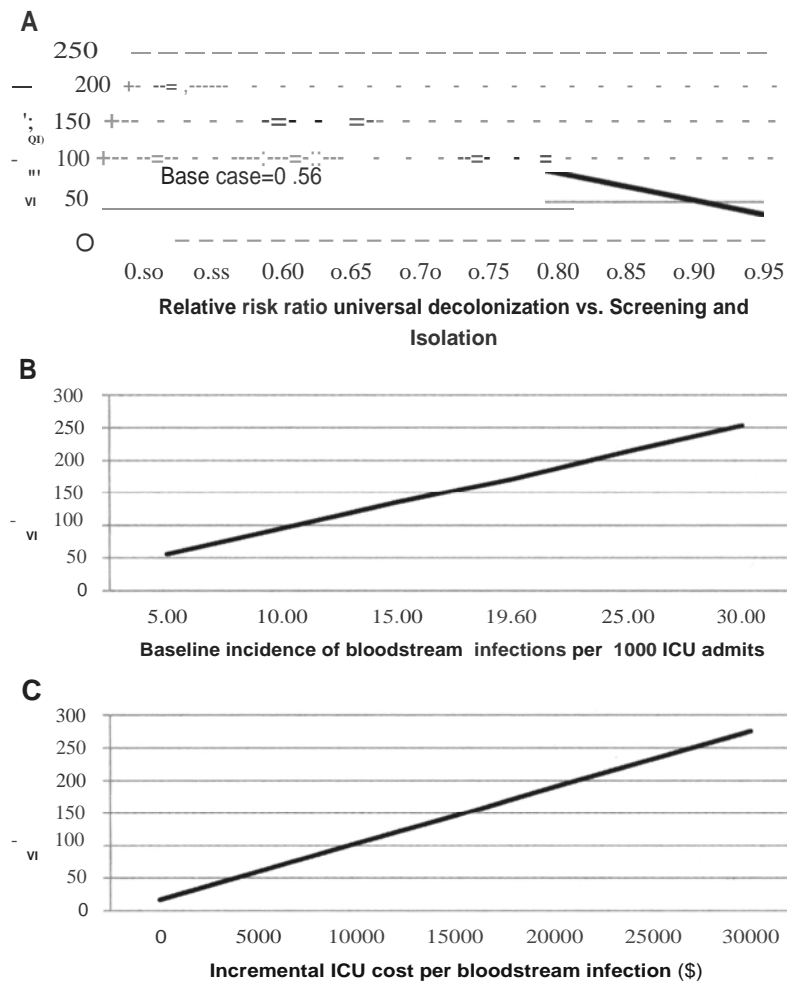Incremental ICU cost per bloodstream infection ($)

FIGURE 1. One-way sensitivity analyses of the estimated cost savings of universal decolonization compared with screening and isolation per intensive care unit (ICU) admission when evaluating (A) the relative reduction (risk ratio) in bloodstream infections, (B) the baseline incidence of ICU bloodstream infections, and (C) the incremental cost of an ICU bloodstream infection.

of universal decolonization was estimated to have lower intervention costs than strategies involving screening, we estimated there would be modest cost savings even if it were not more effective in preventing BSis than screening and isolation alone. Results were also robust to varying assumptions regarding the baseline incidence of ICU BSis (Figure lB) and to the incremental cost of a BSI (Figure IC).

We estimated the differences between the 3 screening strategies under a number of alternative scenarios to the base case (Table 5). Results were robust to a large number of plausible alterations in the assumptions. For example, if the more costly PCR test is used for MRSA screening, the universal decolonization strategy saves $210 per ICU admission versus $171 if chromogenic agar culture is used (scenario 1). If the more costly trade mupirocin is used for decolonization, the universal decolonization strategy saves $85 per ICU admission versus $171 if generic mupirocin is used (scenario 2). When including only costs estimated to be avoidable in the short-term (ie, when all labor is considered to be a "fixed" cost in the time period under consideration), universal decolonization saves $23 per ICU admission (scenario Ml) compared with screening and isolation. Only under the most pessimistic combination of assumptions did the universal colonization strategy cost more than the other two strategies.

DISCUSSION

Universal decolonization has been shown to be a more effective strategy for reducing BSis due to all pathogens than either MRSA screening and isolation or MRSA screening plus targeted decolonization ! We now show that universal de- colonization is also likely to reduce costs. Because savings come both from reductions in BSis (and associated ICU savings) and from lower intervention costs, the benefits of universal decolonization are robust across a wide range of plausible cost and effectiveness assumptions. Consistent with

other studies,[15] we also found that a strategy of screening and targeted decolonization , although not as cost-beneficial as universal decolonization, also resulted in lower costs and fewer BSis than screening and isolation alone.

For a hospital with 1,000 ICU admissions per year, we estimate that universal decolonization would prevent 9 BSis and potentially save approximately $171,000 annually com- pared with screening and isolation. The majority of the estimated savings ($155,000) are associated with expected reductions in BSis. Because the combined cost of chlorhex-idine-impregnated cloths and generic mupirocin is similar to the cost of screening cultures, the balance of the savings ($17,000) is primarily related to savings from reducing the number of patients placed on contact precautions. Using our base case cost assumptions, intervention costs will be similar under both strategies only if the percentage of patients placed on contact precautions is similar, which is highly unlikely given the lack of screening testing under universal decolonization, or if we assume no incremental labor costs for donning gloves and gowns.

A strategy of universal decolonization has been shown to reduce BSis by over 40%,[9] and most of the savings from implementing that strategy would come from reducing BSis and the associated ICU-days. The magnitude of the actual savings at any given institution will largely depend on the ability to realize cost reductions from fewer infections. Using estimates from the literature, we assumed that each infection prevented would avert 3.3 ICU-days and potentially save $18,000. The estimated cost per ICU-day that we used was based on hospital charges that were then adjusted downward by cost-to-charge ratios.[16] As such, it may be thought of as an estimate of long-run average cost. For any given hospital, the savings from averting infections is likely to be substantially less and will depend, for example, on staffing flexibility and the value of alternative uses for the freed-up bed-days. [17,18]

Nevertheless, the cost-savings of the universal decolonization strategy should be realized even by those institutions with excess capacity or staffing that is hard to reduce in the short term. Even when using a very conservative estimate of variable costs (one not including any labor costs), universal decolonization still dominates the other 2 strategies. We note also that our analysis is otherwise conservative in that we have not included any productivity or time costs associated with reduced morbidity.

In addition, because overall intervention costs were similar or lower in our base case estimates, the universal decolonization strategy was the most cost-saving strategy, even under assumptions of minimal effect in reducing BSis compared with screening and isolation alone.

The effectiveness estimates for the prevention strategies were derived from a single trial that included mostly com- munity hospitals, although they were largely representative of US hospitals. [9] Results could vary in hospitals with different patient characteristics, such as proportion of MRSA carriage, or different BSI rates. (The REDUCE MRSA trial focused on community hospital ICUs that may have lower BSI rates than ICUs in academic or specialty cancer care hospitals.) Nevertheless, our sensitivity analyses indicate that the results were robust to changes in those parameters. We did not measure the absolute savings of each strategy compared with no intervention. Among the

TABLE 5. Sensitivity Analyses of Cost Savings of 3 Intensive Care Unit (ICU) Strategies to Reduce ICU Bloodstream Infection per 1,000 ICU Admissions

Scenario number and description	Cost (saving) per admission of universal decolonization, $US	
	Compared with screening and isolation	Compared with targeted decolonization
Base case	(171)	(100)
One-way sensitivity		
1. Assume MRSA screening is done using polymerase chain reaction test ($48)	(210)	(140)
2. Assume use of trade mupirocin ($94)	(85)	(23)
3. Assume time to don and doff gloves and gown is 2 minutes	(190)	(119)
4. Assume 30 nurse and 6 physician visits per ICU-day	{151}	(80)
5. Assume no incremental labor costs associated with contact precautions	(153)	(82)
6. Assume 20% of patients arriving at ICU under screening and isolation and targeted decolonization strategies have history of MRSA and are placed on contact precautions	(228)	(160)
7. Assume 5% of patients arriving at ICU under screening and isolation and targeted decolonization strategies have history of MRSA and are placed on contact precautions	(134)	(60)
8. Assume I0.8% of patients arriving at ICU under universal decolonization have history of MRSA and are placed on contact precautions (ie, the same percent as for the other strategies)	(128)	(57)
9. Assume incremental cost of bloodstream infection is $2,880 (estimate of short-run variable costs)	(41)	(34)
IO. Assume incremental cost of bloodstream infection is $35,000	(299)	{166}
11. Assume relative risk of bloodstream infection in universal decolonization strategy compared with screening and isolation strategy is 0.4912 (rather than 0.5612)	(196)	(125)
12. Assume relative risk of bloodstream infection in universal decolonization strategy compared with screening and isolation strategy is 0.6512 (rather than 0.5612)	(140)	(69)
Multiway sensitivity		
MI. Include only those costs estimated to be short-run variable costs (scenarios 5 and 9)	(23)	(16)
M2. Combine assumptions least favorable to universal decolonization strategy (scenarios 2, 5, 8, 9, and 12)'	94	92
M3. Combine assumptions most favorable to universal decolonization strategy (scenarios I, 4, 6, IO, and 11)	(507)	(367)

NOTE. Data differ from those given in the text due to rounding; data in parentheses are savings. MRSA, methicillin-resistant *Staphylococcus aureus.*

' Scenario 7 was excluded because it was considered implausible for the universal decolonization strategy to have a higher percentage of patients on contact precautions given that no MRSA testing is performed in this strategy.

hospitals in the REDUCE MRSA trial, screening and isolation was the longstanding gold standard,[12] and that is the strategy to which the other strategies were compared. Any gains attained by screening and isolation before the baseline period were not quantified. Nevertheless, the cost savings of the universal decolonization arm over screening and isolation alone and targeted decolonization is valid. Because we used a static model, we could not explicitly account for possible changes in resistance or herd effects. However, the results of the trial upon which our base case epidemiological assumptions were based incorporated those effects to the extent that they occurred during the period of the trial. The use of a static model also meant that sensitivity analyses (for example, those in which the incidence of BSis were varied) were not dynamically linked to other parameters, such as MRSA carriage rates, to which they might, in actuality, be related.

Widespread and long-term use of chlorhexidine and mupirocin may engender drug resistance.[19,20] From the perspective of this study, increased resistance would be tantamount to reduced effectiveness of universal decolonization. However, the effect of universal decolonization on

reducing BSis does not need to be large for that strategy to be preferred. Finally, our perspective was primarily that of the healthcare system and resource use, and so we did not address issues relating to hospital reimbursement.

A strategy of universal decolonization for patients admitted to the ICU would both reduce BSis and likely reduce health- care costs compared with strategies of MRSA nares screening and isolation or screening and isolation coupled with targeted decolonization. These findings were robust to a wide range of cost and effectiveness assumptions.

ACKNOWLEDGMENTS

Address correspondence to Susan Huang, MD, MPH, Division of Infectious Diseases, 101 The City Drive South, City Tower, Suite 400, ZC 4081, Orange, CA 92868 (sshuang@uci.edu).

REFERENCES

1. Vincent JL, Rello J, Marshall J, et al. International study of the prevalence and outcomes of infection in intensive care units. *JAMA* 2009;302:2323-2329.

2. United States Government Accountability Office. Healthcare- Associate Infections in Hospitals. Report to the Chairman, Com- mittee on Oversight and Government Reform, House of Rep- resentatives, 2008.

3. Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mor- tality and costs. *Infect Control Hosp Epidemiol* 2011;32:I 01-114.

4. Luce! JC, Paoletti X, Lolom J, et al. Successful long-term pro- gram for controlling methicillin-resistant *Staphylococcus aureus* in intensive care units. *Intensive Care Med* 2005;31:1051-1057.

5. Huang SS, Yokoe OS, Hinrichsen VL, et al. Impact of routine intensive care unit surveillance cultures and resultant barrier precautions on hospital-wide methicillin-resistant *Staphylococ- cus aureus* bacteremia. *Clin Infect Dis* 2006;43:971- 978.

6. Bleasdale SC, Trick WE, Gonzalez IM, Lyles RD, Hayden MK, Weinstein RA. Effectiveness of chlorhexidine bathing to reduce cathet er- associated bloodstream infections in medical intensive care unit patients. *Arch Intern Med* 2007; 167:2073- 2079.

7. Ridenour G, Lampen R, Federspiel J, Kritchevsky S, Wong E, Climo M. Selective use of intranasal mupirocin and chlorhex- idine bathing and the incidence of methiciUin-resistant *Staph- ylococcus aureus* colonization and infection among intensive care unit patients. *Infect Control Hosp Epidemiol* 2007;28:1155-1161.

8. Huskins WC, Huckabee CM, O'Grady NP, et al. Intervention to reduce transmission of resistant bacteria in intensive care. *N Engl J Med* 2011;364:1407-1418.

9. Huang SS, Septimus E, Kleinman K, et al. Targeted versus uni- versal decolonization to prevent ICU infection. *N Engl J Med* 2013;368:2255-2265.

10. Climo MW, Yokoe OS, Warren DK, et al. Effect of daily chlor- hexidine bathing on hospital-acquired infection. *N Engl J Med* 2013;368:533-542.

11. Derde LP, Cooper BS, Goossens H, et al. Interventions to reduce colonisation and transmission of antimicrobial-resistant bacteria in intensive care units: an interrupted time series study and cluster randomised trial. *Lancet Infect Dis* 2013;14:31-39.

12. Perlin JB, Hickok JD, Septimus EJ, Moody JA, Englebright JD, Bracken RM. A bundled approach to reduce methicillin-resistant *Staphylococcus aureus* infections in a system of community hos- pitals. *J Healthc Qual* 2013;35:57-68.

13. Hassan M, Tuckman HP, Patrick RH, Kountz OS, Kohn JL. Cost of hospital-acquired infection. *Hosp Top* 2010;88:82-89.

14. Roberts RR, Frutos PW, Ciavarella GG, et al. Distribution of variable vs fixed costs of hospital care. *JAMA* 1999;281:644-649.

15. Nelson RE, Samore MH, Smith KJ, Harbarth S, Rubin MA. Cost-effectiveness of adding decolonization to a surveillance strategy of screening and isolation for methicillin- resistant *Staphylococcus aureus* carriers. *Clin Microbial Infect* 2010;16: 1740-1746.

16. Dasta JP, McLaughlin TP, Mody SH, Piech CT. Daily cost of an intensive care unit day: the contribution of mechanical venti- lation. *Crit Care Med* 2005;33:1266- 1271.

17. Graves N. Economics and preventing hospital-acquired infec- tion. *Emerg Infect Dis* 2004;10:561-566.

18. Graves N, Weinhold D, Tong E, et al. Effect of healthcare- acquired infection on length of hospital stay and cost. *Infect Control Hosp Epidemiol* 2007;28:280- 292.

19. Richter SS, Diekema DJ, Heilmann KP, et al. Activities of van- comycin, ceftaroline, and mupirocin against *Staphylococcus au- reus* isolates collected in a 2011 national surveillance study in the United States. *Antimicrob Agents Chemother* 2014;58(2):740- 745.

20. Desroches M, Potier J, Laurent F, et al. Prevalence of mupirocin resistance among invasive coagulase-negative staphylococci and methicillin- resistant *Staphylococcus aureus* (MRSA) in France: emergence of a mupirocin-resistant MRSA clone harbouring mupA. *J Antimicrob Chemother* 2013;68(8):1714- 1717.

21. Kang J, Mandsager P, Biddle AK, Weber DJ. Cost-effectiveness analysis of active surveillance screening for methicillin-resistant *Staphylococcus aureus* in an academic hospital setting. *Infect Con- trol Hosp Epidemiol* 2012;33:477-486.

22. Puzniak LA, Gillespie KN, Leet T, Kollef M, Mundy LM. A cost- benefit analysis of gown use in controlling vancomycin-resistant Enterococcus transmission: is it worth the price? *Infect Control Hosp Epidemiol* 2004;25:418-424.

23. Morgan DJ, Pineles L, Shardell M, et al. The effect of contact precautions on healthcare worker activity in acute care hospitals. *Infect Control Hosp Epidemiol* 2013;34:69-73.

24. Courville XF, Tomek IM, Kirkland KB, Birhle M, Kantor SR, Finlayson SR. Cost-effectiveness of preoperative nasal mupirocin treatment in preventing surgical site infection in patients un- dergoing total hip and knee arthroplasty: a cost-effectiveness analysis. *Infect Control Hosp Epidemiol* 2012;33:152-159.

25. Kilgore M, Brossette S. Cost of bloodstream infections. *Am J Infect Control* 2008;36:Sl 72- Sl 73.