*Original Article*

# Cost effectiveness of dressing in the prevention of catheter-related infection in critically ill patients

Edivane Pedrolo[1], Mitzy TR Danski[1], Astrid Wiens[2], Radamés Boostel[1]

[1] Nursing department. Federal University of Paraná, Curitiba, Brazil
[2] Pharmacy department. Federal University of Paraná, Curitiba, Brazil

## Abstract

Introduction: Catheter-related infection is a complication of high morbimortality. The aim was to perform a cost-effectiveness analysis of gauze and medical tape, transparent semi–permeable and chlorhexidine-impregnated dressings for short-term central venous catheter, within the Brazilian Public Healthcare System (Sistema Único de Saúde – SUS) scenario.

Methodology: a decision tree was elaborated in order to evaluate the cost-effectiveness of dressings in the prevention of catheter-related infection in critically ill patients. The outcome was the probability of catheter-related infections prevention. Moreover, only direct medical expenses were considered. Sensitivity analyses were performed to evaluate the model uncertainties.

Results: Chlorhexidine-impregnated dressing presented higher cost-effectiveness when the base case was analyzed (cost of US$ 655 per case prevented, 99% of effectiveness), in comparison to gauze and medical tape dressing (US$ 696, effectiveness of 96%). Dressing changes performed before the recommended period, treatment performed exclusively in inpatient units and high effectiveness of gauze and medical tape dressing were variables that interfered with the results. The probability of death has also demonstrated to have a major impact on cost-effectiveness.

Conclusion: In the context of a Brazilian public hospital, the chlorhexidine-impregnated dressing presented higher cost-effectiveness when compared to the gauze and medical tape dressing or the transparent semi-permeable dressing.

Key words: catheter-related infections; catheterization, central venous; costs and cost-analysis; evidence-based practice; nursing.

## Introduction

Primary bloodstream infection related to central venous catheter (BSI-CVC) is a complication with high morbidity and mortality [1] associated with the use of devices, such as the percutaneous central venous catheter that is widely used in patients admitted to intensive care units (ICUs). In these catheters, the most common route of infection is the extraluminal one, in which the microorganisms present on the patient´s skin or in the hands of the professional that manipulates the device, are the main agents of contamination [2]. Strategies to prevent this complication include dressings for covering the ostium of the catheter, which comprise gauze and medical tape dressing, transparent semi-permeable dressing and chlorhexidine-impregnated dressing. There is worldwide evidence that the correct use of each of these strategies confers protection against BSI [3].

A systematic review evaluating the effectiveness of gauze and medical tape dressing and transparent semi-permeable dressing showed that there is no difference among these dressings regarding the prevention of BSI-CVC. Although there is evidence of an increase in BSI density when using transparent semi-permeable dressing, this evidence is weak, with high risk of bias and needs additional studies [4]. The chlorhexidine-impregnated dressing, a novelty strategy, demonstrates positive results in the prevention of BSI-CVC, with a decrease in colonization (6.5% versus 13.2%) [5] and infection (1.51/1000 versus 5.87/1000 catheters-day), when compared to traditional dressings [6].

Despite the evidence of chlorhexidine-impregnated dressings' effectiveness in the prevention of BSI-CVC, there are no cost-effectiveness studies concerning these technologies for the Brazilian context. Thus, the present study aimed to perform a cost-effectiveness analysis of gauze and medical tape dressing, transparent semi-permeable dressing, and chlorhexidine-impregnated dressing for short-term central venous catheter, within the Brazilian Public Healthcare System (Sistema Único de Saúde – SUS) scenario.

## Methodology

*Modelling*

A cost-effectiveness evaluation was performed through the elaboration of a decision tree for a hypothetical cohort of adult patients. The definition of the cohort was based on an earlier phase of this study, which revealed the following clinical profile [7]: (mean age 48,84 ± 20,11 years, 61,36% male, which were hospitalized in ICU due to traumatic injuries (81,82%), with an Acute Physiology And Chronic Health Evaluation (APACHE II) greater than 25 (54,55%) and were using short-term CVC in subclavian (81,82%), and did not present BSI-CVC or bacteremia through another infectious focus at the time of the catheter insertion. The definition of BSI-CVC adopted in this study was: the first bloodstream infection in patients using a catheter for more than 48 hours, with no other infectious focus identified [8]. The outcome analyzed was the probability of preventing a BSI-CVC.

The studied technologies included gauze and medical tape dressings (standard dressing used in the institution), transparent semi-permeable dressing and chlorhexidine-impregnated dressing, which were compared to each other. The evaluation was conducted over three months, based on the maximum hospitalization time of patients diagnosed with BSI-CVC in a Brazilian hospital institution linked to SUS, according to previous findings from this study. The analysis was conducted considering the perspective of the SUS. The American dollar (US$) was considered as the base currency for the cost calculations, in amounts referring to 03/11/2017 (1 American Dolar – US$ = 3,3061 Brazilian Real – R$). BSI-CVC-related death was considered when there was persistence of the microorganism in the bloodstream even after the drug treatment was instituted, with progressive worsening of the clinical status and evolution to death.

*Costs and probabilities*

Information about the costs, regarding the BSI-CVC and the technologies, were obtained from a retrospective observational study [7] conducted previously using medical records of patients with BSI-CVC, hospitalized in a Brazilian public hospital. Only direct medical costs were considered, including: 1) treatment (antimicrobials and/or antifungals and supplies for its administration); 2) hospitalization during the BSI-CVC treatment; 3) cultures for diagnosis and control; and 4) replacement of the infected catheter, when performed. The cost of drugs and supplies was based on the three last purchases. In order to correct the values for 2017, the inflation rate

(CPI) was used. No discount rates were applied. The remaining costs, regarding hospitalization and procedures, were based on the SUS' Management System of Procedures, Medicines and OPM (SIGTAP). For the dressings that are not standardized in the hospital, a price consultation with companies specialized in the commercialization of medical and surgical materials was conducted and the average value to purchase each dressing was used to calculated.

The hospitalization cost for patients who did not develop BSI-CVC was estimated based on their hospitalization costs. The parameter was a study describing an increase of 3.1 times in the hospitalization time of patients with infection in relation to non-infected ones [9]. In the total cost of each BSI episode, the average hospitalization time of the patients, prior to the development of the complication until the end of the treatment, was computed. For the cost-effectiveness analysis of the different technologies, dressing changes were considered as recommended by CDC guidelines: gauze and medical tape dressing every 48 hours; and transparent semi-permeable dressing and chlorhexidine-impregnated dressing every seven days [8]).

*Sensitivity analysis*

After the model construction and the definition of the base case, univariate and bivariate sensitivity analysis were performed, based on the minimum and maximum values found for the costs, the probabilities and the effectiveness of the technologies under study. Complementary analyses, based on the worst case scenario (higher costs, higher probabilities and lower effectiveness) and on the best case scenario (lower costs, lower probabilities and greater effectiveness), were also conducted. The Incremental Cost-Effectiveness Ratio (ICER) was calculated only for the non-dominated strategies.

For the sensitivity analysis, the dressing change frequency, as reported by clinical trials that evaluated the technologies in real scenarios, was applied. They are: gauze and medical tape dressing 1.63 ± 0.34 days [10]; transparent semi-permeable dressing between 40.5 and 68.5 hours [11]; and chlorhexidine-impregnated dressing 71 hours [12]. It was estimated that the catheter was changed every nine days, based in data of the previously study conducted for this research [7]. The modeling and sensitivity analysis were performed using the software *TreeAge Pro* 2015. The study was approved by the Research Ethics Committee under opinion 1.344.051.

## Results

The decision tree is presented in Figure 1. The effectiveness of the evaluated dressings was established based on the probability of occurrence of BSI-CVC when each technology was used, extracted from two systematic reviews for each technology [3-5]. The probability of infections in each dressing was calculated. The effectiveness of technologies and other data for the construction of the tree are shown in Table 1.
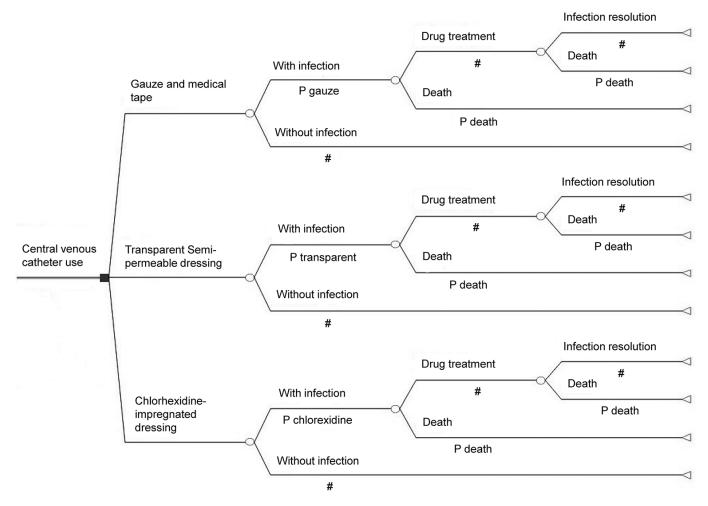
The analysis performed suggests that the most cost-effective strategy is the chlorhexidine-impregnated dressing for ostium occlusion of short-term CVC, which cost US$ 655 per case prevented and 99% of effectiveness. The remaining dressings are dominated. Further data are presented in Table 2.

The sensitivity analyses that changed the result of the cost-effectiveness evaluation, are presented in the sequence. The tornado diagram demonstrated that the variables with the greatest impact on the outcome were the likelihood of BSI occurrence when using transparent semi-permeable dressing (ranged from 0.023 to 0.075), followed by the probability of death due to infection (ranged from 0.20 to 0.50). The probability of BSI-CVC occurrence when chlorhexidine-impregnated dressing was applied had the lowest impact in the analysis (ranged from 0.012 to 0.019).

The univariate sensitivity analysis for the "death" variable demonstrated that the chlorhexidine-impregnated dressing represented the lowest amount invested for each case of infection prevented, when the probability of death is less than 0.425. In the range between 0.425 and 0.500, this relationship changes and the most cost-effective technology becomes the transparent semi-permeable dressing. When the probability of infection with gauze and medical tape dressing is varied to less than 0.021, this is the

**Figure 1.** Decision Tree.



P = probability of the event; # = 1 less the probability of the event of the opposite arm [7]

**Table 1.** Data of the model.

| Variable | Mean | Sensitivity analysis | Reference |
|---|---|---|---|
| **Effectiveness of the technologies (likelihood of catheter-related infection)** | | | |
| Gauze and medical tape dressing | 0.427 | 0.012 – 0.048 | [3-4] |
| Transparent Semi-Permeable Dressing | 0.0321 | 0.023 – 0.075 | [3-5] |
| Chlorhexidine-impregnated dressing | 0.0129 | 0.012 – 0.019 | [4-5] |
| Probability of death | 0.249 | 0.000 – 0.500 | [8] |
| **Costs** | | | |
| Patient with BSI-CVC with "ceasing of infection" outcome | U$ 4.518,50 | U$ 556,18 – U$ 22.559,61 | SIGTAP + hospital costs |
| Patient with BSI-CVC with "death" outcome | U$ 2.074,13 | U$ 701,75 – U$ 13.987,45 | SIGTAP + hospital costs |
| Patient with BSI-CVC with "death" outcome before starting treatment | U$ 1.310,82 | U$ 441,34 – U$ 12.757,91 | SIGTAP + hospital costs |
| Patient without BSI-CVC | U$ 577,83 | - | SIGTAP + hospital costs |
| Changing of gauze and medical tape dressing* | U$ 3,54 | U$ 0,70 – U$ 11,32 | Hospital costs |
| Changing of Transparent Semi-permeable Dressing* | U$ 9,17 | U$ 4,58 – U$ 22,93 | Hospital costs |
| Changing of Chlorhexidine-impregnated dressing* | U$ 42,54 | U$ 21,27 – U$ 106,36 | Price query in specialized companies |

*considering an average catheter time of 9.11 ± 5.60 days, as evidenced in a previous step of our research.

technology that represents smaller investment per case of infection prevented. In the range between 0.021 and 0.03, this relationship is reversed, and the most cost-effective dressing becomes the chlorhexidine-impregnated dressing.

Bivariate sensitivity analyses were also performed considering the worst and best case scenario. In these cases, there were changes when the following parameters were used: 1) minimum cost: none of the technologies were dominated, with gauze and medical tape dressing being the most cost-effective technology. The ICER was US$ 600 for the transparent semi-permeable dressing and US$ 606 for the chlorhexidine-impregnated dressing; 2) cost with dressing change, according to the stay time of each technology described in clinical trials: gauze and medical tape dressing was dominated, and the most cost-effective technology was transparent semi-permeable dressing. The ICER was US$ 1,161 for the chlorhexidine-impregnated dressing.

When the values of cost, probability and effectiveness are changed at the same time, and considering the minimum, average and maximum values for each of these factors, there was a change in the analysis result while using the minimum cost or maximum effectiveness. Considering the minimum cost and maximum effectiveness, the gauze and medical tape dressing was the most cost-effective technology,

costing US$ 578 and presenting an effectiveness of 0.99, with the other technologies being dominated. Maximum cost and maximum effectiveness also indicated gauze and medical tape dressing as the most cost-effective technology, costing US$ 804 per case prevented and presenting an effectiveness of 0.99, with the other technologies being dominated. Likewise, average cost with maximum effectiveness indicated the gauze and medical tape dressing as the most cost-effective, costing US$ 620 and presenting an effectiveness of 0.99, with the other technologies being dominated. Finally, when using the minimum cost and minimum effectiveness, gauze and medical tape dressing were the most cost-effective technology, with a cost of US$ 577 per case prevented and effectiveness of 0.95. However, in this scenario, chlorhexidine-impregnated dressing is not dominated and the ICER is equal to zero.

## Discussion

The chlorhexidine-impregnated dressing is cost-effective in relation to the gauze and medical tape dressing and the transparent semi-permeable dressing, in the context of a Brazilian public hospital. If incorporated in the institution under study, the use of chlorhexidine-impregnated dressing will require an investment of US$ 655 for each case of BSI-CVC

**Table 2.** Results of the cost-effectiveness evaluation of the dressings for short-term central venous catheter.

| Strategy | Cost (U$) | Incremental cost (U$) | Effectiveness | Incremental effectiveness | ICER |
|---|---|---|---|---|---|
| Chlorhexidine-impregnated dressing | 655,01 | | 99% | | |
| Transparent semi-permeable dressing | 670,77 | 15,76 | 97% | -2% | Dominated |
| Gauze and medical tape dressing | 696,01 | 41,00 | 96% | -3% | Dominated |

ICER – Incremental Cost-Effectiveness Ratio.

prevented. Considering that each episode of BSI-CVC costs, on average, US$ 2,937 for the hospital, according to research data, it is possible to observe that the incorporation of this technology will represent significant savings for the hospital institution. The strategy currently used by the institution – gauze and medical tape dressing – requires investment of US$ 696 for each case of BSI-CVC prevented, however, it has an effectiveness 3% lower.

Economic analyses of dressings for CVC performed in the United States [13], in France [14-15] and in the United Kingdom [16] also showed that chlorhexidine-impregnated dressing was the most cost-effective. Furthermore, those analyses demonstrated that the incorporation of chlorhexidine-impregnated dressing resulted in savings for health institutions. Thus, the results presented in this study suggest that the same situation could occur in the Brazilian scenario.

A systematic review with meta-analysis reinforces these findings, since it demonstrated that chlorhexidine-impregnated dressing is cost-effective even when the incidence of BSI-CVC is low – 0.35/1000 catheters-day [5]. This information becomes relevant because, until recently, this dressing was only indicated for institutions in which the catheter-related infection rates remained high, even after the implementation of bundles and other prevention measures [8].

When performing the sensitivity analysis, the cost attributed to a BSI episode interfered with the cost-effectiveness evaluation. When the minimum cost for an episode of infection was applied, gauze and medical tape dressing was more cost-effective. This scenario was repeated in all the sensitivity analysis in which the minimum cost was used. However, when the average effectiveness was applied, the ICER demonstrated that, for a 1% effectiveness gain with the use of transparent semi-permeable dressing, an investment of US$ 600 would be necessary. For each 2% of increase in effectiveness with the use of the chlorhexidine-impregnated dressing, an investment of US$ 606 would be necessary. When the minimum effectiveness of the technologies was applied, the ICER of chlorhexidine-impregnated dressing was equal to zero, with an effectiveness gain of 3%. Thus, even though the institution achieves only a minimum reduction of BSI-CVC rates with the use of chlorhexidine-impregnated dressing, this will still be the most cost-effective strategy.

It is necessary to consider that the minimum cost found in this research refers to patients who have been diagnosed with BSI-CVC during their hospitalization in ICUs. However, the clinical picture presented was not serious and the patients were able to continue with the treatment of this complication exclusively in clinical units. As demonstrated in this research and also in other studies, the ICU daily cost has great impact on the result of the economic evaluation [14-15]. Thus, it may be suggested that the gauze and medical tape dressing is more cost-effective for patients who are not hospitalized in ICUs. Yet, the use of chlorhexidine-impregnated dressing for patients hospitalized in ICUs is still indicated. This result was corroborated by a cost-effectiveness study conducted in the United Kingdom, which indicated the use of the chlorhexidine-impregnated dressing for adult patients hospitalized in ICUs or in high-dependency units [17].

Another variable that affected the result of the economic evaluation was the effectiveness of each dressing. When the probability of occurrence of BSI-CVC used was the lowest established in the literature, gauze and medical tape dressing was more cost-effective. However, it should be considered that, in this scenario, the probability of occurrence of BSI-CVC is the same for gauze and medical tape dressing and for chlorhexidine-impregnated dressing. The latter presents probability reports with little variation (0.012 to 0.019), while gauze and medical tape dressing has a large variation in the likelihood of infection (0.012 to 0.048). It is important to consider infection rates and probability of occurrence of this complication in each unit in order to implement the results of this evaluation.

The systematic review that assessed the interference caused by the dressing change frequency of transparent semi-permeable dressing on BSI-CVC, showed that there is no significant difference in the occurrence of this outcome when the dressing change is performed between two and five days, in comparison to the change performed between five and fifteen days. The most frequent change increases dressing costs in 50% [18].

In the present analysis, the dressing change frequency had an impact on the result of the cost-effectiveness evaluation. When the change frequency established in clinical trials was used rather than the one recommended by the manufacturer, transparent semi-permeable dressing was the most cost-effective technology, followed by chlorhexidine-impregnated dressing. In this scenario, in order to gain an effectiveness of 3% with the use of chlorhexidine-impregnated dressing, it would be necessary to invest US$ 1,161.

Other authors corroborate with this result by indicating that the amount of dressings per day was one of the variables that most influenced the cost-effectiveness analysis, together with hospitalization

time, price per unit of the chlorhexidine-impregnated dressing and ICU daily costs [15]. On the other hand, a study that evaluated the cost of chlorhexidine-impregnated dressing and transparent semi-permeable dressing, with dressing change every three days and every seven days, showed that the use of chlorhexidine-impregnated dressing leads to savings for the hospital in both periods of change, with a probability of BSI greater than 0.141% for change every three days, and greater than 0.212% for change every seven days [14].

The variable that presented the greatest impact on the sensitivity analysis, according to the tornado diagram, was the probability of death due to BSI-CVC. A case-control study that evaluated mortality rates due to this complication demonstrated that the risk of death varies according to the severity of the patient's state at the ICU admission, the etiological agent causing the infection, and the ICU hospitalization time prior to the infection [19].

In Brazil, there are no national data referring to the mortality rate by BSI-CVC, although a national service reporting this complication since 2010. As shown in the sensitivity analysis, the death rate due to BSI is a variable that interferes with the cost-effectiveness ratio among technologies. If the probability of death is lower than 0.425, chlorhexidine-impregnated dressing is more cost-effective. Regarding probability of death ranging between 0.425 and 0.500, transparent semi-permeable dressing becomes the most cost-effective technology. Considering these results, it is suggested that the probability of death for patients with BSI-CVC in the ICU interferes in the choice of the most cost-effective technology and should be considered for implementation of this research results.

The prevention of BSI-CVC is an important approach in the national health scenario, as this is a complication that impairs hospital institutions and can be prevented. Authors reinforce this idea by demonstrating that BSI-CVC prevention programs are cost-effective and save between 9.61 to 15.55 years of life, adjusted by quality (QALY) [20]. Thus, the present research contributes to the incorporation of the most cost-effective technologies in the prevention of BSI in the reality of developing countries. However, it is necessary to consider that dressings' effectiveness is directly related to the adoption of other measures of BSI-CVC prevention, such as hand hygiene, use of maximal sterile barrier during catheter insertion, choice of insertion site, use of chlorhexidine solution, early removal of catheter, among other measures already recommended in the literature [21].

The results of this research are of extreme relevance to developing countries, as it presents a cost-effectiveness analysis of technologies focused on the prevention of BSI-CVC, closer to the reality of these countries. It is known that the most prevalent etiological agent in the BSI-CVC, the infrastructure for care of patients with this complication, the access to technologies, the qualification of the professionals that attend this patient and the system of surveillance and infection control differ widely between developed and developing countries [22]. The economic evaluations of technologies for CVC dressings were published only in developed countries, and this research contributes to the diffusion of economic assessments to developing countries.

The fact that the chlorhexidine-impregnated dressing is not standardized in the hospital studied is one of the limitations of this analysis. Other limitations are the fact that the costing assessment was done retrospectively, indirect and intangible costs were not considered and only a single outcome was analyzed. In addition, the presence of biofilm in the infections was not considered, although studies indicate that its presence interferes in the clinical profile of the infection [23]. Finally, the need of considering the individual characteristics of each patient, which may interfere with the probability of BSI-CVC occurrence, with its clinical evolution and with the mortality rate associated with this complication, is another limitation. The present research has not received any type of funding, and the authors have no conflicts of interest in relation to the results presented.

## Conclusion

The most cost-effective dressing, in the context of a hospital linked to SUS, is the chlorhexidine-impregnated dressing, which presented the lowest amount invested for each case of BSI-CVC prevented. The sensitivity analysis revealed that the cost-effectiveness ratio is altered when the dressing changes are performed before the recommended period, when the treatment is performed exclusively in an inpatient unit, and when the effectiveness of the gauze and medical tape dressing is high. The probability of death had a major impact on cost-effectiveness.

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## Corresponding author

Edivane Pedrolo.
PhD in nursing. Postgraduate program in nursing at the Federal University of Paraná, Brazil. Curitiba, Paraná, Brazil.
Pref. Lothario Meissner Avenue, 632, third floor, Jardim Botânico, zip code: 80.210-170. Curitiba, Paraná, Brazil.
Phone: +55 41 3535-1680.
E-mail: edivanepedrolo@gmail.com

**Conflict of interests:** No conflict of interests is declared.