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STANFORD BYERS CENTER FOR BIODESIGN

VALUE-BASED HEALTHCARE AND HEALTH ECONOMICS RESEARCH IN HEALTHCARE FINANCING

SINGAPORE BIODESIGN

CASE STUDY SERIES

MAIN AUTHORS

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Prof Graves has made contributions of international significance, publishing over 250 articles in top-ranking peer reviewed journals such as JAMA, BMJ, AIDS, Health Economics, Clinical Infectious Diseases, Lancet Infectious Diseases, The Journal of Infectious Diseases and Emerging Infectious Diseases.

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She has previous experience in medical diagnostic equipment sales in the UAE market. She began her career working in computer integrated medical interventions at Nanyang Technological University, collaborating with clinicians across various specialties and hospitals. She spent many years working on a surgical robot for urological indications that spun out into Biobot Surgical Pte Ltd. She graduated with a B.Eng in Computer Engineering and a MSc. in Biomedical Engineering from NTU.

INTRODUCTION

Health care economics is a segment of economic study pertaining to the value, effectiveness, and efficiency in medical care and health care services. Resource scarcity is a large primary economic challenge faced by Governments while running a healthcare system. The healthcare services are constantly put under the pressure of demand and supply. As health budgets cannot increase indefinitely, it is pertinent that the available resources be optimized to maintain the balance.

Within Singapore, with the rapid growth of healthcare costs, Singapore's healthcare expenditure would have to grow rapidly by an average of 6.35% per year [1]. However, as of 2021, Singapore's GDP has never grown this fast and to cater for this healthcare growth, resources would have to be channeled from other areas of the economy. In an effort to keep up with the exponential growth of healthcare costs, Singapore and other countries are looking for ways to limit healthcare spending. Since there is never enough money to provide every service to all patients at all times, resources need to be concentrated on the highest value services and treatments.

In order to manage the resources optimally, some healthcare systems prefer a blended approach where the public hospitals are supplemented by private healthcare providers, some are government owned, and others are more market driven. Some examples are shown below:

Examples:

1. The UK has a largely government-owned and managed health service called the National Health Service (NHS). The arm of government focused on value for money and cost effectiveness is the National Institute of Health and Care Excellence (NICE) and is heavily incentivised to identify and fund only good value healthcare.
2. Australia adopts a blended healthcare landscape, where 50% of healthcare costs are government funded and the rest is funded by private insurance and providers. There is some use of cost-effectiveness data in the decision making but it's not as much as in the UK.
3. The US healthcare system is mostly driven by market forces. While government-funded healthcare is a large part of the market, it is not universal, and the private sector has traditionally been heavily involved in determining their own reimbursement coverage in the provision of healthcare. Nevertheless, the Patient-Centred Outcomes Research Institute is a non-profit institute created through the 2010 Affordable Care Act to provide evidence-based research to improve the performance of health services.

Cost-Effectiveness and its Use

The development of population health measurements and ethics, leading to the concept of modern cost effectiveness and Quality Adjusted Life Years (QALYs) was led by Professor Alan Williams [2]. Professor Williams argued that all procedures should be ranked and prioritized based on economics so that activities that generate more gains to health per dollar of resources should take priority over ones that had lower gains. He theorized that if cost effectiveness was used to decide which services to provide, the general standard of health in a given community would be elevated. To illustrate how value can be perceived, Figure 1 provides a theoretical illustration of how health benefits accumulate (QALYs) as healthcare spending rises.

One example that would put this into context is Singapore's latest foray into setting up a local proton beam therapy center. This treatment modality is expected to cost more but will be able to use cutting-edge technology to effectively target and destroy cancer cells. However, the cost to build one center is about

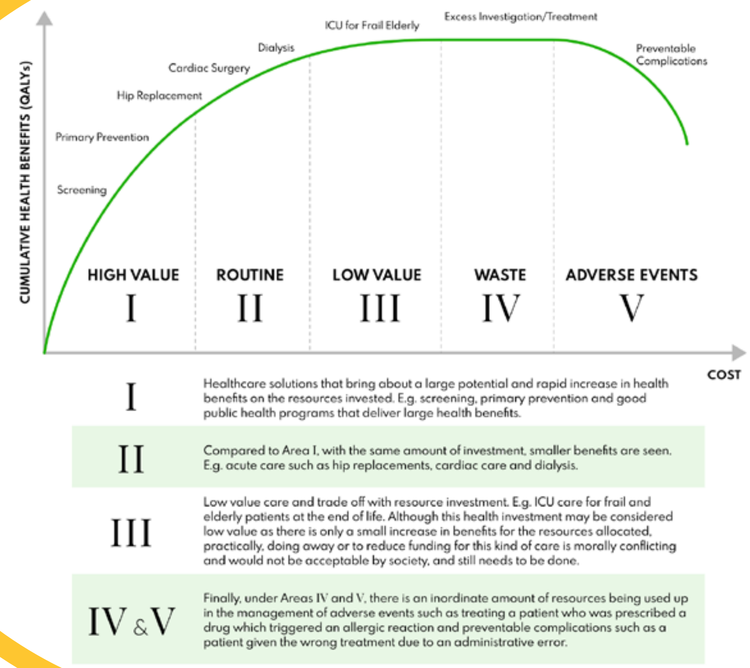


FIGURE 1: Cumulative Health Benefits, measured as Quality Adjusted Life Years (QALYs), over Cost of the Benefit

$150 million [3], not including the manpower cost and overhead expenses. Moreover, Singapore plans to have 3 centers, at the National Cancer Centre Singapore, Mount Elizabeth Novena Hospital and the Proton Therapy Centre at Biopolis. So, for this half-a-billion-dollar investment to be a good decision, it needs to deliver enormous health benefits.

To support the choice of cost-effective solutions that deliver greater health benefits, health economists use an incremental cost effectiveness ratio (ICER) framework to demonstrate the effectiveness of a competing or alternative solution compared to a baseline (i.e., current standard of care or current existing services).

Whilst most innovations in the past significantly increased costs in order to enjoy the added health benefits, the introduction of value-based healthcare and the need to reduce healthcare expenditure has driven new innovation companies to strive to balance maximum willingness to pay against tangible improvements

FIGURE 2: Cost Effectiveness Framework; X-axis Shows the Health Benefits, Y-axis Shows the Cost of the Proposed Intervention

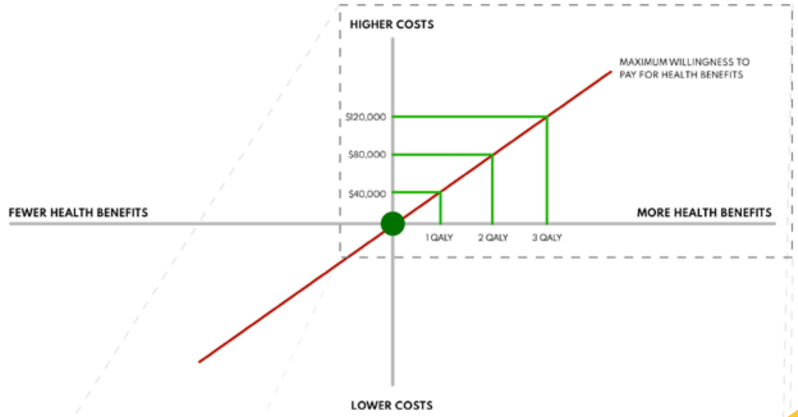


FIGURE 2A: An Example of How to Calculate the Maximum Willingness to Pay Per QALY Gained Against the Value a Treatment Option Provides

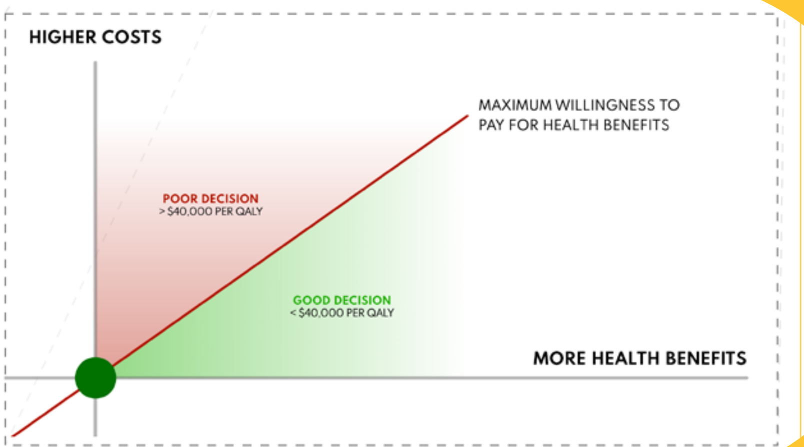


FIGURE 2B: Zoomed-In Graph Depicting How Cost Effectiveness Translates To a Good or Poor Decision

in health benefits. Figure 2 shows a framework to identify where a decision is supported and the maximum amount that a payor is willing to pay by measuring health benefits in terms of QALYs. Figure 2A shows that a payor, in this case is the government of a country, is willing to pay $40,000 per extra QALY and if an innovation costs less than the threshold amount (in this example, $40,000 per QALY), it will be considered as a good and cost-effective investment as depicted in Figure 2B. Different countries have different ways of deriving this threshold and how it is defined.

Another way to quantify value is from QALYs gained by understanding how the health quality changes with length of life as shown in Figure 3. Health benefits shown by QALYs summarise the avoided morbidity and reduced risk of mortality respectively.

The x-axis on Figure 3 shows the length of an individual's life in years (quantity of life) and the y-axis shows a measure of health-related quality of life, whereby 1 means being in perfect health, and 0 means that the individual has died. Figure 3A is an example of perfect health over entire length of life and in Figure 3B, the graph shows the difference in QALY with and without medical intervention. A baseline comparator is established where the patient does not get the treatment or innovation and they are dead by year 2. The Quality of Life (QOL) falls quite steeply from 1 to 0. Comparatively, when a treatment is given to the patient, the patient's life is prolonged by 2 years and an improved quality of life is noticed. The area between these 2 lines quantifies the QALY gain delivered by this treatment.

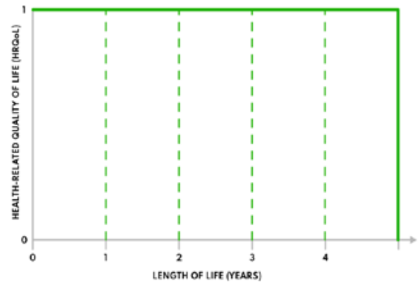


FIGURE 3A: Ideal QALY without any changes to quality of life

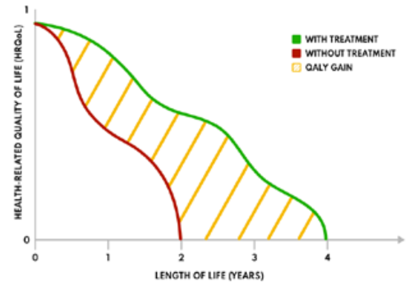


FIGURE 3B: Typical example of how QALY changes over a lifespan

FIGURE 3: Health-Related Quality of Life over Length of an Individual's Life

Interpreting findings for decision making

Knowing how QALY relates to measurable health outcomes will allow decision makers to make an informed decision on allocating their resources towards healthcare interventions. In certain Asian countries like Japan and Thailand, regulatory authorities also require a health tech assessment to be carried out before regulatory approvals can be given.

Some innovations are easy to implement, get adopted quickly and start improving cost effectiveness and efficiency while some others require a lot of investment of cost, take time to implement and do not show any cost effectiveness for many years. Below are some examples from previously published literature:

Innovation Case Studies

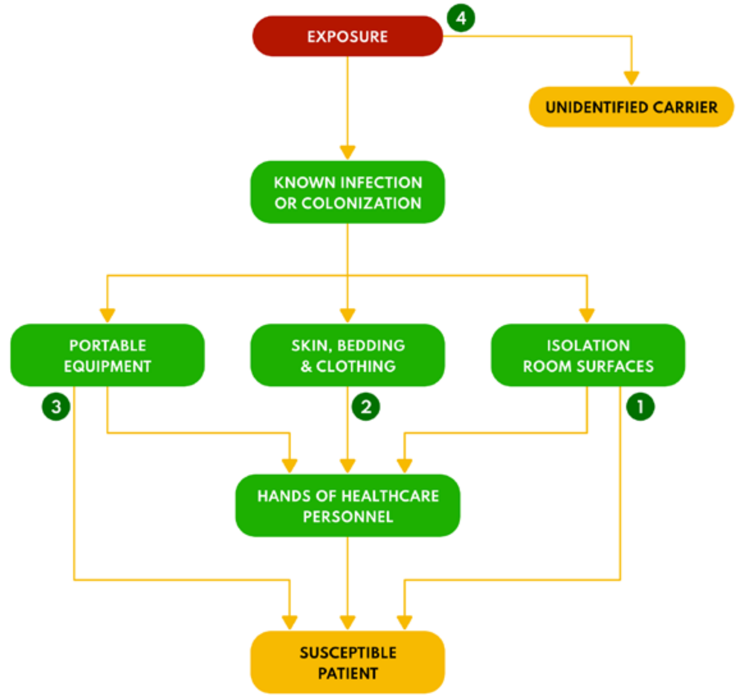
1. Use of Short Message Service (SMS) for Post-Hospitalization Cardiac Rehab [4]

   A study in Australia used SMS (Short Message Service) notifications aimed at patients with coronary heart disease to improve post hospitalization adherence to cardiac rehabilitation. The intervention showed that patients who received these timely notifications had reduced cholesterol, blood pressure and BMI and behavioural changes in an increase in physical activity and reduction in smoking. The patients reported that they found that the text messages were useful, easy to understand and appropriate in frequency.

   A cost-effectiveness study on the program was published and found that for a cohort of 50,000 patients with documented coronary heart disease, the intervention was expected to lead to 313 fewer myocardial infarctions, 230 fewer strokes and 441 additional QALYs. Providing this intervention to this cohort was expected to cost the health system 1.7 million AUD. This cost, however, would be outweighed by the future cost-savings associated with fewer cardiovascular events and the intervention is expected to lead to an overall saving of 4.6 million AUD for the health system [4]. Hence, adoption was an obvious choice.

2. Infection Prevention and Cleaning [5]

   Infection transmission in an acute care setting is very complex and involves the compliance of multiple stakeholders. Reducing the risk of infection and the transmission of bugs involves both maintaining personal hand hygiene and frequent infrastructure cleaning. Figure 4 shows an example of infection transmission in an acute care setting. Typically, patients colonized or infected with health care-associated pathogens shed organisms onto their skin, clothing, and nearby environmental surfaces. Susceptible patients



NOTE:
Four sources of transmission: (1) contamination of surfaces after terminal cleaning of isolation rooms resulting in risk of acquisition by patients subsequently admitted to the same room; (2) contamination of surfaces in isolation rooms resulting in risk for contamination of health care personnel hands; (3) contamination of portable equipment; and (4) contamination of surfaces in rooms of unidentified carriers of health care-associated pathogens.

FIGURE 4: Infection Transmission in an Acute Care Setting
Adapted from Donskey, C. J., 2013 [6]

may acquire pathogens through direct contact with surfaces or equipment or via the hands of health care personnel [6].

A study of cleaning regimes from 11 Australian hospitals was conducted to evaluate the effectiveness, cost-effectiveness, and implementation outcomes around a hospital cleaning bundle. In order to improve hospital cleaning, an evidence-based cleaning bundle based on a systematic review of peer-reviewed articles was developed by experts with the inputs of cleaners, so it was likely to be acceptable and implemented (Figure 5) [7].

The 11 hospitals were viewed as independent organisations and customised their own implementation plan, taking into account the hospital's characteristics, context, existing policies and practices. The outcome measures were quantitative and looked at the thoroughness of hospital cleaning using fluorescent marking gel, hospital rates for Clostridium difficile infection (CDI), Staphylococcus aureus bacteremia (SAB), and vancomycin-resistant enterococci (VRE) infections and at the cost-effectiveness of the implementation of this new cleaning intervention.

It was noted that from the point of implementation of the cleaning bundle, hospitals noticed an increased cleaning frequency in wards and bathroom. Infection rates decreased drastically; the risk of VRE was reduced by 37% and the risk of SAB by 18% (Figure 6).

The cost-effectiveness of the intervention was evaluated using ICER and net monetary benefit (NMB), which offered different summaries of the change in costs versus health benefits. Based on these simulations, there was an 80% probability that it was going to be cost-effective and the average cost per QALY gained was $19,000 which was comfortably below the threshold used in Australia of $40,000 per QALY. However, this was a labour-intensive process and required expensive manpower for high quality cleaning. The decision on whether this process was a cost-effective one was not as straightforward.

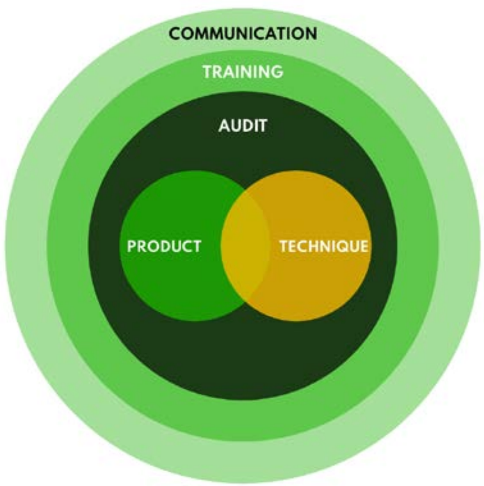
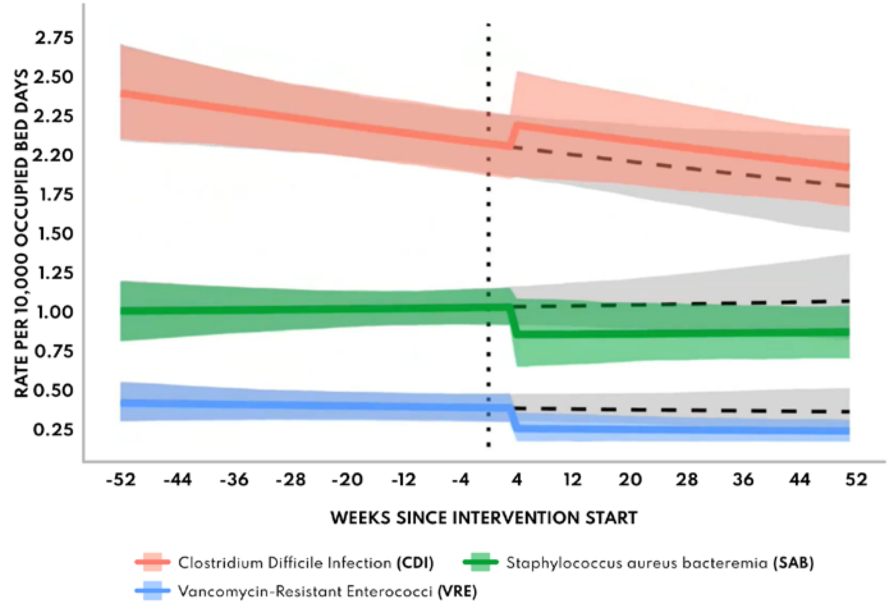


FIGURE 5: Evidence Based Bundle Developed by Experts. *Adapted from Allen, M. et al., 2018 [7]*



Ribbons are 95% prediction intervals. Grey shading shows expected infection rates with no intervention.

FIGURE 6: Estimated Changes in Healthcare Associated Infection Rates Before and After the Intervention. *Adapted from Mitchell, B.G. et al., 2019 [5]*

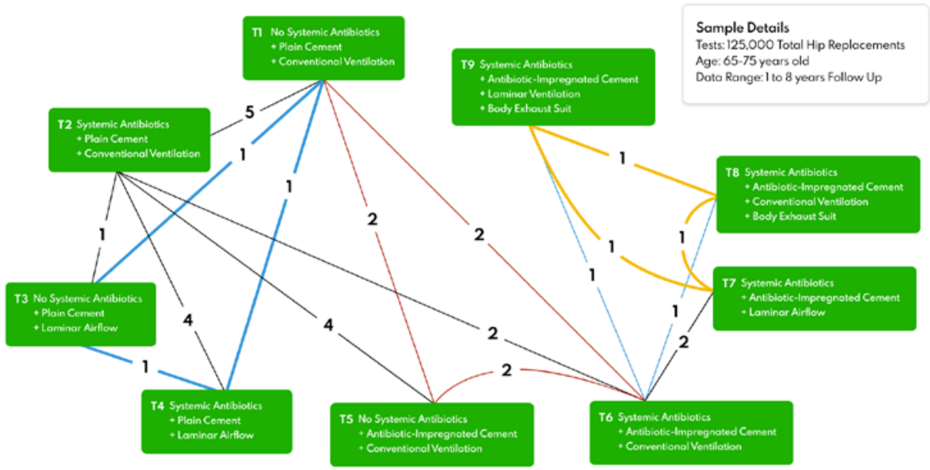
To mitigate this problem, the team looked to automate the solution. A trial was done with a cleaning robot, and although the robot was not effective as a human cleaner, the team was able to prove that it worked. This not only improved the cost-effectiveness ratio, but also spawned a whole industry around automated cleaning and disinfection robots, particularly useful in a pandemic. This example proved that while a solution could achieve desired health benefits, the cost-effectiveness does play a pivotal role in its implementation.

3. Laminar Air flow for Operating Rooms [8]

The concept of providing laminar air flow to operating rooms has been around since the mid-80s. In the past, numerous trials have shown that this approach worked to curb infection rates. However, recently, there has also been controversy around this approach and Figure 7 shows a summary of the various papers published on managing infection risks for total hip replacement. Typical costs for constructing and installing laminar air flow for each operating room is ~USD$60,000-$90,000.

Some studies have noted that there is a marginal difference between adopting a conventional ventilation system versus a laminar ventilation system in operating rooms. Even when there were statistically significant differences in some measures between the 2 groups, the actual differences were not clinically significant and did not consistently favor any one group over the other. As shown in Figure 7, authors of the study compare the operating room for T6 (systemic antibiotics with antibiotic impregnated cement and conventional ventilation) with T7 (systemic antibiotics with antibiotic impregnated cement and laminar airflow) and found that laminar airflow could potentially increase infection risk, even though it is the standard of care everywhere. The study concluded that they did not find convincing evidence in favour of the use of laminar airflow over conventional ventilation for prevention of Total Hip Replacement-related surgical site infections.

Based on another study in an Australian hospital where 30,000 primary hip replacement procedures were done, using laminar airflow, 179 more patients had infections which cost around $30,000 to treat and a possibility of 4 deaths (127 QALYs lost), total loss of $4.5M [9]. So setting up a laminar air flow would not be considered a cost effective solution as costs are higher and health benefits are lower.



NOTE:
The lines represent direct evidence comparisons; boxes represent infection control strategies involving multiple infection control measures; the numbers on the lines represent the number of comparisons.
The three-way loops in **bold** lines represent loops only formed by a multi-arm trial.

FIGURE 7: The Mixed Treatment Comparison Network Consisting of 12 Studies with 9 Infection Control Strategies. *Adapted from Zheng, H. et al., 2014 [8]*

CONCLUSION

Healthcare resources are scarce and as a society it is important to use them efficiently. There is an opportunity cost for not using cost-effective services. Cost-effectiveness data can be used by decision makers to improve the overall welfare of society. The methods to quantify and measure the cost-effectiveness of a given intervention are readily available, powerful and often used to demonstrate that some innovations are better investments than others.

REFERENCES

1. Future of Singapore: Growing Old With You | DBS Vickers Online Trading. (2021). Retrieved 18 August 2021, from https://www.dbs.com.sg/vickers/en/research/featured/160802_featured_future_of_singapore_growing_old_with_you.page
2. Williams, A. (2008). The Ideas and Influence of Alan Williams: Be Reasonable, Do it My Way!. Radcliffe Publishing.
3. Kurohi, R. (2019). Centre to offer proton beam therapy for cancer by early 2020. Retrieved 18 August 2021, from https://www.straitstimes.com/singapore/health/centre-to-offer-proton-beam-therapy-for-cancer-by-early-2020
4. Burn, E., & Jan, S. Cost-effectiveness ofTobacco Exercise and diet MEssages (TEXT ME), a text message-based intervention for secondary prevention of cardiovascular disease Edward Burn, MSc1, Son Nghiem1, PhD, Stephen Jan, PhD2, Julie Redfern, PhD2, Anthony Rodgers, MBChB, PhD2, AravindaThiagalingam, MBChB, PhD3, 4, Nicholas Graves, PhD1, Clara K. Chow, MBBS, PhD2, 4.
5. Mitchell, B. G., Hall, L., White, N., Barnett, A. G., Halton, K., Paterson, D. L., ... & Graves, N. (2019). An environmental cleaning bundle and health-care-associated infections in hospitals (REACH): a multicentre, randomised trial. The lancet infectious diseases, 19(4), 410-418.
6. Donskey, C. J. (2013). Does improving surface cleaning and disinfection reduce health care-associated infections?. *American journal of infection control, 41*(5), S12-S19.
7. Allen, M., Hall, L., Halton, K., & Graves, N. (2018). Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy. *Infection, Disease & Health, 23*(2), 107-113.
8. Zheng, H., Barnett, A. G., Merollini, K., Sutton, A., Cooper, N., Berendt, T., ... & Graves, N. (2014). Control strategies to prevent total hip replacement-related infections: a systematic review and mixed treatment comparison. BMJ open, 4(3), e003978.
9. Merollini, K. M., Crawford, R. W., Whitehouse, S. L., & Graves, N. (2013). Surgical site infection prevention following total hip arthroplasty in Australia: a cost-effectiveness analysis. American journal of infection control, 41(9), 803-809.

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