Infection, Disease & Health (2018) 23, 87—92

Available online at www.sciencedirect.com

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Research paper

Reducing length of stay to improve *Clostridium difficile*-related health outcomes

David C. Brain [a,*], Adrian G. Barnett [a], Laith Yakob [b], Archie Clements [c], Thomas V. Riley [d], Kate Halton [a], Nicholas Graves [a]

[a] *Institute of Health and Biomedical Innovation, Queensland University of Technology, 60 Musk Ave, Kelvin Grove, Queensland, 4059, Australia*
[b] *Faculty of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine, Keppel Street, Bloomsbury, London, WC1E 7HT, United Kingdom*
[c] *Research School of Population Health, Australian National University, Canberra, ACT, 0200, Australia*
[d] *School of Biomedical Sciences, The University of Western Australia, 35 Stirling Hwy, Perth, Western Australia, 6009, Australia*

Received 22 November 2017; received in revised form 9 January 2018; accepted 9 January 2018
Available online 1 March 2018

KEYWORDS
Clostridium difficile;
CDI;
LOS

Abstract *Background: Clostridium difficile* infection is a serious hospital-acquired infection, causing negative outcomes for those who are afflicted by it. Hospital length of stay is known to be a risk factor for transmission and significant reductions in infection numbers can be realised if transmission is reduced.
Methods: A Markov model was constructed to compare the impact that five alternative health-care scenarios had on total *C. difficile* infections, QALYs gained and total number of patients requiring treatment in ICU. A previously published stochastic transmission model for *C. difficile* informed scenario effectiveness, while other parameters were estimated from published literature, administrative datasets and expert opinion.
Results: Reducing inpatient LOS disrupts transmission of *C. difficile* and results in a large reduction of total infections. In turn, an increase in QALYs is expected when the number of infections is reduced. A reduction in infections reduces the number of ICU admissions, which is likely to have a large economic benefit in the Australian setting. Coupling a reduction in overall inpatient LOS with a 'traditional' infection control intervention, such as hand hygiene or antimicrobial stewardship, improves results further than reducing LOS on its own.
Conclusion: Implementing a LOS-focused intervention would be a practical challenge, especially for clinicians who already juggle high demand. However, it is not unattainable with the right local endorsement and could have significant benefits for health services.

* Corresponding author.
E-mail addresses: david.brain@qut.edu.au (D.C. Brain), a.barnett@qut.edu.au (A.G. Barnett), laith.yakob@lshtm.ac.uk (L. Yakob), director.rsph@anu.edu.au (A. Clements), thomas.riley@uwa.edu.au (T.V. Riley), k.halton@qut.edu.au (K. Halton), n.graves@qut.edu.au (N. Graves).

https://doi.org/10.1016/j.idh.2018.01.001

Highlights

- Reducing overall LOS has positive impacts on *Clostridium difficile*-related health outcomes.
- A reduction in *C. difficile* infections is expected when LOS is reduced.
- Economic benefits are likely when infections are reduced and QALYs are gained.

Introduction

Patient length of stay (LOS) has long been linked with influencing transmission of *Clostridium difficile* infection (CDI) [1,2]. It has previously been shown that the longer a patient stays in hospital, the greater their chances of infection, as risk rises cumulatively for each day in hospital [3–5]. It is also clear that there are economic consequences when there is an increase in *C. difficile* infections [6,7]. Analysis of prior occupant's CDI status has likewise shown a significant risk for acquisition when CDI was previously detected [8].

Despite a good understanding that in the last decade hospital LOS has steadily reduced in the majority of Australian hospitals, there has not yet been a quantification of the impact that a reduction in LOS could have on *C. difficile* outcomes in the Australian setting. This study aimed to determine the extent to which *C. difficile*-related health outcomes could be improved by better management of inpatient LOS. Despite LOS-reduction not being categorised as a 'traditional' infection control measure, a reduction in LOS is a plausible byproduct of a system-wide improvement in patient management.

Methods

A Markov model was constructed to compare five different healthcare scenarios and measure the influence that these scenarios had on the following health outcomes: total number of *C. difficile* infections avoided, number of quality-adjusted life years (QALYs) gained, and number of patients requiring admission to the intensive care unit due to suffering a severe *C. difficile* infection. The structure of the model has been described in detail elsewhere [7] and a pictorial representation is in Appendix 1. The clinical effectiveness of each scenario was estimated from the results of a previously published, stochastic transmission model which assessed the increase or decrease in *C. difficile* transmission as a result of that scenario [9]. All scenarios were compared to 'standard care', which was assumed to be: a current antimicrobial stewardship programme or antimicrobial restriction policy (AMS), a hand hygiene and environmental cleaning programme for the whole hospital, and the capacity to undertake fecal microbiota transplant (FMT). Rates consistent with those previously published were used [9]: the baseline level of antimicrobial exposure in a hospital at any given time was assumed to be 50% of inpatients [10,11]; the average time for gut flora to be properly restored was 90 days post-infection [12]; and the average length of stay for all hospitalised patients was assumed to be 5.8 days [13]. The scenarios considered are described in Table 1.

The scenarios and their chosen level of efficacy were informed by a panel of experienced clinicians and infection control practitioners. The scenarios chosen for this study were deemed to be realistically achievable in the Australian setting. However, due to the flexibility of the mathematical model that informed the efficacy of each scenario, the chosen level for analysis can be manipulated according to local requirements, if desired. For example, if there is local evidence suggesting a smaller reduction in LOS is more plausible for their setting, analysts in that setting can easily alter the efficacy parameters in the model, to produce a more locally-relevant result. The research team is happy to share the model, which is built in Microsoft Excel, on a suitable open access platform for others to evaluate different strategy efficacy levels that are not explicitly shown in these results.

Table 1 Scenarios included in the analysis.

Scenario	Description
LOS 1	A reduction in the average LOS by 1 day (from 5.8 days to 4.8 days)
LOS 2	A reduction in the average LOS by 2 days (from 5.8 days to 3.8 days)
LOS & AMS 1	LOS & AMS bundle where the average LOS is reduced by 1 day and the number of people exposed to antibiotics is reduced from 50% to 40%.
LOS & AMS 2	LOS & AMS bundle where the average LOS is reduced by 2 days and the number of people exposed to antibiotics is reduced from 50% to 40%.
LOS & HYG	LOS & hygiene improvement bundle where the average LOS is reduced by 1 day and the transmission rate of infection is halved by the effectiveness of a hygiene improvement program

Data sources, assumptions and related limitations

The best available evidence was sought, but as is typical for modelling studies, it was obtained from a range of sources, both within Australia and from published work outside the Australian setting. Table 2 shows data sources for each input variable used in the Markov model. Health utility weights were assigned to all health states in the model, with the majority of estimates derived from published studies. Expert opinion was used for health states that could not be informed from the literature. This approach is appropriate given the prohibitive cost and practical

Table 2 Input variables for the Markov model.

Variable	Fixed value	Range	Distribution	Reference
Health utilities	**(Daily)**			
At-risk	0.92	0.84–0.96	Uniform	
Non-severe	0.82	0.72–0.93	Uniform	[14]
Severe	0.71	0.50–0.72	Uniform	[14]
Discharged vulnerable 1	0.85	0.75–0.90	Uniform	[15]
Recurrent infection	0.61	0.50–0.72	Uniform	[15]
Discharged vulnerable 2	0.80	0.70–0.85	Uniform	[15]
Discharged healthy	0.88	0.84–0.92	Uniform	[16]
Costs	($AUD)	($AUD)		
Diagnosis (non-severe)	$58.48	$52.63–$64.33	Uniform	[17]
Diagnosis (severe)	$29.24	$26.32–$32.16	Uniform	[17]
Diagnosis (recurrent inf)	$16.08	$14.48–$17.69	Uniform	[17]
Hospital (non-severe)	$800	$720–$880	Uniform	[18]
Hospital (severe)	$3000	$2700–$3300	Uniform	[18]
Hospital (recurrent inf)	$1900	$1710–$2090	Uniform	[18]
Treatment (non-severe)	$3.71	$3.34–$4.08	Uniform	[19]
Treatment (severe)	$47.43	$42.69–$52.17	Uniform	[19]
Treatment (recurrent inf)	$99.69	$89.72–$109.66	Uniform	[19]
Transition probabilities		**(alpha; beta)**		
At-risk to:				
Remain at-risk	0.273	(236461; 629636)	Beta	[20]
Non-severe	0.0001	(93; 866004)	Beta	[20]
Severe	4.61E-06	(4; 866093)	Beta	[20]
Discharged healthy	0.725	(628408; 237689)	Beta	[20]
Dead	0.001	(1131; 864966)	Beta	[21]
Non-severe infection to:				
Remain non-severe	0.752	(70; 23)	Beta	[20]
Dead	0.000	(0.1; 93.1)	Beta	[20]
Discharged vulnerable 1	0.247	(23; 70)	Beta	[20]
Severe infection to:				
Remain severe	0.75	(3; 1)	Beta	[20]
Dead	0.000	(0.1; 4.1)	Beta	[20]
Discharged vulnerable 1	0.25	(1; 3)	Beta	[20]
Discharged vulnerable 1 to:				
Remain discharged vulnerable 1	0.829	(85; 632)	Beta	[20]
Censored	0.012	(1.3; 715.7)	Beta	[20]
Recurrent infection	0.110	(11.3; 705.7)	Beta	[20]
Dead	0.047	(4.9; 712.1)	Beta	[20]
Discharged vulnerable 2 to:				
Remain discharged vulnerable 2	0.846	(22.9; 166.1)	Beta	[20]
Censored	0.021	(0.6; 188.4)	Beta	[20]
Recurrent infection	0.126	(3.4; 185.6)	Beta	[20]
Dead	0.005	(0.1; 188.9)	Beta	[20]
Recurrent infection to:				
Remain recurrent infection	0.671	(19.3; 181.7)	Beta	[20]
Dead	0.059	(1.71; 199)	Beta	[20]
Discharged vulnerable 2	0.268	(7.7; 193.3)	Beta	[20]
Discharged healthy to:				
Remain discharged healthy	0.999	(847653; 88)	Beta	[20]
Dead	0.0001	(9.4; 623113)	Beta	[20]

difficulty of gathering health utility estimates from primary sources. The rate that patients move between compartments in the model was informed by hospital administration data, obtained from the Western Australian Department of Health. An absence of individual clinical test results meant that the classification of illness severity was simplified for this study. Patients who suffered an infection but did not require an ICU stay were categorized as having 'non-severe' infection, while those who had an infection and a concurrent ICU stay were categorized as having 'severe' infection. This assumption may have resulted in an overestimation of severe cases, however, some simplification was required based on data availability. The probability of dying from infection was estimated using the detailed cause of death data recorded in the Western Australian administrative dataset. The probability of dying from non-infective health states was estimated from Australian life tables [14]. Further assumptions relating to the model include an inability to move between infective categories (e.g. from 'non-severe' to 'severe') and not accounting for the possibility of being admitted with a community-acquired infection (i.e. treating all infections as hospital acquisitions). Such assumptions are necessary and not uncommon, given data availability or concerns with the accuracy of certain aspects of collected data. The model used in this study is flexible and can be updated to incorporate new evidence if it becomes available.

Results

Reducing patient LOS across the hospital is likely to result in an improvement in *C. difficile*-related health outcomes. Compared to the current environment, each scenario yielded gains in QALYs and reductions in the total number of *C. difficile* infections per annum in Australia. There were also reductions in the number of patients requiring ICU care, when each scenario was compared to standard treatment.

The modelled reduction in CDIs per annum in Australia is in Fig. 1. All scenarios showed a reduction in the average number of *C. difficile* infections that could be expected if LOS-improving scenarios were implemented across Australia. It is evident that the greatest reduction in infections was experienced when a combination of LOS and hygiene improvement was implemented, with 2690 infections avoided per year. The worst performing scenario, reducing LOS by one day but not in conjunction with another intervention, still reaped significant rewards, with 1102 infections per year avoided compared to usual care.

There were also large gains in the number of QALYs that could be expected when a LOS scenario was successfully implemented, compared with usual care. Combining LOS reduction with a hygiene improvement intervention delivered the highest QALY gains (37 gained). All scenarios, including reducing average LOS on its own, by as little as one day, resulted in an increase in QALYs. These results are shown in Fig. 2.

Discussion

The results show that *C. difficile*-related health outcomes could be significantly improved if the average LOS of all admitted patients was reduced. These findings are logical, given the increased risk that an inpatient stay has on becoming infected and with risk diminishing further if a well implemented infection control program is running in parallel.

Given the results of this study, it is realistic to assume that there are large economic gains to be made by improving LOS. A reduction in *C. difficile* infections would result in a reduction in hospital resource use, reduction in treatment costs and most significantly, a large reduction in bed costs. This is particularly the case when CDI-related ICU admissions are reduced, given the high cost of an ICU bed. However, calculating the economic gains accurately is problematic at this stage, given that there has yet to be an attempt to thoroughly describe and quantify the costs associated with an intervention that specifically addresses reducing overall inpatient LOS. Further work in this area would be an important addition to the evidence base and likely to be of interest to hospital decision-makers who are tasked with managing high demand for services with non-increasing budgets.

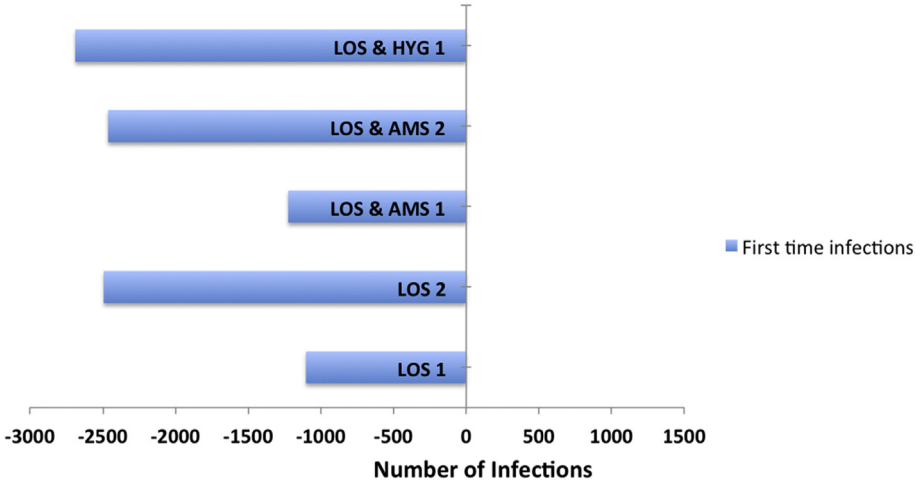

Figure 1 Average change in number of *C. difficile* infections, compared to usual care.

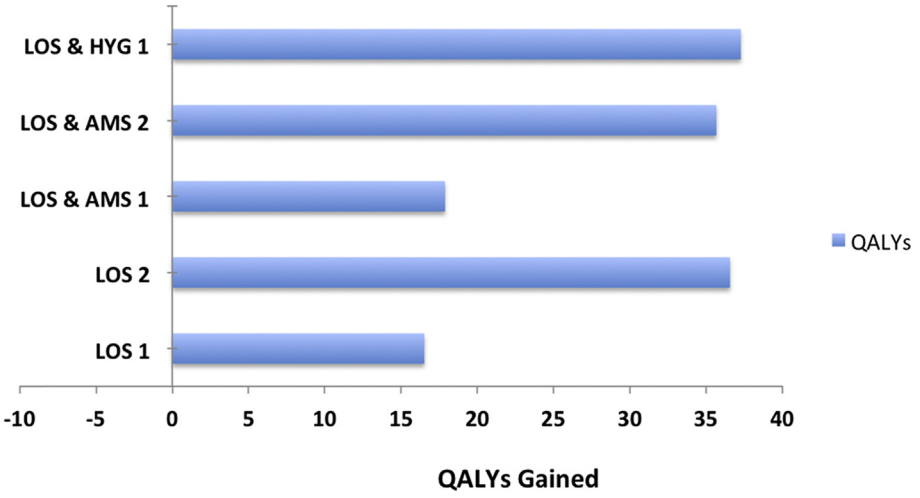

Figure 2 Average change in QALYs, compared to usual care.

Translating the results into practice will also be difficult. There are practical issues with attempting to further reduce LOS, especially considering clinicians are already tasked with juggling high occupancy rates and high patient throughput. Impacting time-to-safe-patient-discharge is influenced by numerous factors within the healthcare system, making its navigation complex and requiring further strategic consideration. Numerous clinical and administrative processes are required before a patient can be discharged and we hypothesise that speeding the administrative process is most likely to be where improvements in reducing LOS might be seen. This is noted elsewhere in the literature, where improvements in physician to nurse communication, standardization of discharge practice for an entire facility and the use of tailored discharge plans were frequently noted as being processes that should be scrutinised and maintained to ensure appropriate and timely discharge is happening in hospitals [22—24]. The maximum achievable reduction in overall LOS is likely to be site-specific and varied, due to a number of locally-appropriate factors. This study hypothesises reductions in average LOS that may be achievable in some settings and not in others. However, the model is of value because it can be used to analyse numerous different LOS scenarios, with the results helping to inform *C. difficile*-related decision-making.

It is also worth noting that whilst infection control is a critical component of the healthcare system, it is an overarching support rather than a stand-alone aspect of a hospital. There is no guarantee that cash gains will be directly noticed by the infection control department, despite a reduction in infections. What there will be is an improvement in hospital efficiency, as an intervention that effectively reduces infection risk will free up beds, allowing extra capacity to treat patients. The economic benefits of interventions that reduce *C. difficile* infections are unlikely to relate to the financial bottom line for the infection control department, but downstream effects, such as savings in other areas of the hospital or contribution to a reputational gain are plausible.

Conclusion

C. difficile is a problematic infection in the Australian hospital setting and efforts to reduce its transmission need to remain a priority for infection control departments. This study has shown that limiting overall inpatient LOS has the capacity to disrupt transmission rates, yielding a reduction in total infections and ICU stays. The results also show that by reducing average LOS, we could expect to see an increase in QALYs and a reduction in *C. difficile*-related costs, although further study is required to formally quantify the latter. Implementing a LOS-focused intervention would be a practical challenge but is not unattainable with the right clinical and decision-maker endorsement of its value.

Ethics

Not applicable.

Authorship statement

DB conceptualised and wrote the manuscript.

LY, AB, TR, AC, KH & NG revised and critiqued the final manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

This work was supported by the Centre of Research Excellence in Reducing Healthcare Associated Infections, which was funded by the National Health and Medical Research Council (NHMRC) grant GNT1030103. The research presented in this article is solely the responsibility of the authors and does not reflect the views of the NHMRC.

Provenance and peer review

Not commissioned; externally peer reviewed.

Acknowledgments

DB would like to acknowledge the work of Josh Toner who created the Markov model diagram on a no-fee basis.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.idh.2018.01.001.

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