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Economic Impact of Outbreaks of Norovirus Infection in Hospitals

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Norovirus is highly infectious and can spread rapidly in healthcare settings, consuming resources and resulting in longer hospital stays.[1–4] Although the economic impact of specific past outbreaks has been reported (eg, a 2007 outbreak of norovirus infection at Johns Hopkins Hospital cost an estimated $650,000),[5] these costs may not be generalizable. We developed an economic computer simulation model to assist policy makers, hospital administrators, infection control professionals, and other healthcare workers in determining how much to invest in norovirus prevention and control interventions above and beyond existing infection control measures.

Using Microsoft Excel (Microsoft) with a Crystal Ball (Oracle) add-in, we developed a stochastic susceptible-exposed-infectious-recovered (SEIR) compartment model to simulate the economic effects of various outbreaks of norovirus infection from the hospital perspective. The simulation progressed in 1-day time steps. At the start of each simulation run, a single infectious patient entered a hospital ward filled with susceptible patients. Each simulation day, the number of patients in the susceptible (S) and infectious (I) compartments and the reproductive rate (R_0) of norovirus (range, 3.179–4.301; mode, 3.74)[6] determined the number of newly infected case patients based on the following formula:

$$\text{number of new case patients per day} = \beta \text{SI} = \left(\frac{R_0}{\text{infectious period duration}}\right) \times \text{SI}.$$

Each newly infected patient then moved from the susceptible compartment to the exposed compartment, where he or she remained for a brief incubation period (randomly selected from a 1–2-day uniform distribution)[1,4] and then progressed to the infectious compartment, where he or she remained for the duration of the infectious period (randomly selected from a

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triangular 1–8-day distribution, peaking on day 3).[1] Each patient in the infectious compartment had a probability of becoming symptomatic of 66.29% (range, 63.46%–69.12%).[2,7]

A symptomatic norovirus infection resulted in an extended length of stay (LOS) for patients, who had to be hospitalized for the duration of their symptoms (4–6 days).[1,3,4] As a result, these patients occupied hospital beds that could have been used by other patients, costing the hospital lost revenue ($1,794.26 per bed-day)[8] in a manner described by Graves.[9] Because a recent Centers for Disease Control and Prevention guideline suggests that contact isolation precautions need to be maintained until symptoms resolve, plus extra time to account for viral shedding after infection, our baseline simulations assumed that the LOS attributable to norovirus infections was the duration of the patient's symptoms.[10] Asymptomatic patients did not have an increased LOS.

After the infectious period, a patient then moved into the recovered (R) compartment, where he or she was immune to reinfection for the remainder of the simulation, because norovirus infection produces short-lived immunity for 6–14 weeks.[1,4]

Sensitivity analyses varied the hospital ward size and norovirus-attributable LOS (from 4–6 days to 2–3 days).[1,3,4] Each presented result is a mean value from 1,000 trials. Table 1 shows how cost to the hospital varied by ward size and day after introduction of an infectious case. Costs increased with ward size and outbreak duration. Assuming no prior immunity and homogeneous mixing within the ward, an unmitigated outbreak will eventually infect everyone in the ward. On average, this takes 15 days for the 10-bed ward and 17 days for the 15-bed ward. By day 20, a majority of patients in all larger ward sizes were infected.

Table 1 helps calculate the incremental cost savings of detecting and controlling a norovirus outbreak earlier. For example, detecting and containing a norovirus outbreak in a 10-bed ward on day 3 instead of day 5 could save $11,623 ($32,762 minus $21,139). In a 15-bed ward, containing an outbreak on day 3 instead of day 5 could save $15,838 ($38,914 minus $23,076), and containing it on day 7 instead of day 10 saves $18,016. A shorter LOS attributable to norovirus infection yielded cost savings ranging from $335 (day 17 instead of day 20 in a 10-bed ward) to $35,978 (day 7 instead of day 10 in a 50-bed ward). The larger the ward size and the more symptomatic cases there are, the higher the costs.

To our knowledge, our study is the first to utilize economic modeling to quantify the potential economic burden of norovirus to the hospital. Understanding cost from the hospital perspective can help hospitals determine how much should be invested in norovirus surveillance to aid early detection and timely infection control to prevent additional spread.[1]

Our economic analysis was by design conservative about estimating the cost of norovirus infection. By focusing on lost bed-days, it did not include additional potential costs associated with an outbreak, such as increased diagnosis and cleaning, patient isolation, and missed work days of infected staff. While ward costs may vary by hospital location and circumstance (eg, ward at or under capacity, staff available), it is impossible to model every potential scenario. Therefore, we relied on the Graves costing method, which focuses exclusively on lost bed-days.[9]

Our study has additional limitations. All models are simplifications of real life and cannot fully represent every possible outcome. Our model assumed homogeneous mixing within a hospital ward. It also used a number of estimates drawn from different sources.

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The cost savings of early detection and control of infection are not inconsequential. This potential savings could pay for control efforts. Our economic model quantified the potential cost of outbreaks of norovirus infection under different circumstances and the potential value of early detection and control. These results are for general benchmarking and could help policy makers, hospital administrators, infection control specialists, and other decision makers determine how much to invest in norovirus surveillance and control. Future studies could delineate the cost and efficacy of such measures.

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TABLE 1

Economic Impact of an Outbreak of Norovirus Infection on the Hospital

	Duration of outbreak, days							
Variable	**3**	**5**	**7**	**10**	**12**	**15**	**17**	**20**
LOS of 2–3 days								
Ward size of 10 beds								
All cases, mean no.	4	6	7	9	9	10	10	10
Symptomatic cases, mean no.	3	4	5	6	7	7	7	7
Cost, mean ± SD	10,638 ± 3,480	16,565 ± 5,102	21,702 ± 5,427	26,319 ± 4,571	27,958 ± 4,092	29,149 ± 3,735	29,506 ± 3,674	29,841 ± 3,584
Ward size of 15 beds								
All cases, mean no.	4	6	9	12	13	14	14	15
Symptomatic cases, mean no.	3	4	6	8	9	10	10	10
Cost, mean ± SD	11,147 ± 3,743	18,728 ± 6,840	26,980 ± 8,548	36,123 ± 7,719	39,653 ± 6,625	42,402 ± 5,613	43,363 ± 5,321	44,103 ± 2,213
Ward size of 50 beds								
All cases, mean no.	4	8	14	26	34	41	44	47
Symptomatic cases, mean no.	3	6	10	18	23	28	30	32
Cost, mean ± SD	12,312 ± 4,620	23,804 ± 11,817	42,555 ± 22,758	78,533 ± 34,086	100,166 ± 34,016	122,831 ± 27,967	131,953 ± 23,627	139,522 ± 19,547
LOS of 4–6 days								
Ward size of 10 beds								
All cases, mean no.	4	5	7	9	9	10	10	10
Symptomatic cases, mean no.	3	4	5	6	7	7	7	7
Cost, mean ± SD	21,139 ± 6,761	32,762 ± 9,968	43,214 ± 10,644	52,817 ± 8,882	56,086 ± 7,981	58,537 ± 7,414	59,305 ± 7,166	60,083 ± 6,988
Ward size of 15 beds								
All cases, mean no.	4	6	9	12	13	14	15	15
Symptomatic cases, mean no.	3	4	6	8	9	10	10	10
Cost, mean ± SD	23,076 ± 8,205	38,914 ± 14,439	55,675 ± 17,314	73,691 ± 15,459	80,428 ± 13,283	85,665 ± 11,483	87,344 ± 10,971	88,637 ± 10,638
Ward size of 50 beds								
All cases, mean no.	4	8	14	27	34	44	44	47
Symptomatic cases, mean no.	3	5	10	18	23	28	30	31
Cost, mean ± SD	25,071 ± 9,194	48,420 ± 23,532	86,497 ± 44,908	159,468 ± 66,174	203,329 ± 65,877	248,938 ± 53,034	267,269 ± 44,232	282,525 ± 36,434

NOTE. All costs are in 2010 $US, converted with a 3% discount rate. LOS, length of stay attributable to norovirus infection; SD, standard deviation.