Modelling resource requirements and physician staffing for a virtual urgent medical care strategy to reduce transfer of long-term care home residents to acute care hospitals

Fahad Razak MD MSc[1,2,3], Saeha Shin MPH[3]*, Frances Pogacar BCS[3,4]*, Hae Young Jung MSc[3], Laura Pus MBA[5], Andrea Moser MD MSc[2,6], Lauren Lapointe-Shaw MD PhD[2,7], Terence Tang MD[2,8], Janice L. Kwan MD MPH[2,9], Adina Weinerman MD MHSc[2,10], Shail Rawal MD MPH[2,7], Vladyslav Kushnir PhD[3], Denise Mak PhD[3], Danielle Martin MD MPP[5,11], Kaveh G. Shojania MD[2,10], Sacha Bhatia MD MBA[2,5], Nick Daneman MD MSc[2,10], Payal Agarwal MD[5,11], Geetha Mukerji MD MSc[5,11], Michael Fralick MD PhD[3,9], Moira K. Kapral MD MSc[2,7], Matthew Morgan MD MSC[2,9], Brian Wong MD[10‡], Timothy Chan PhD[3,4‡], Amol A. Verma MD MPhil[1,2,3‡]

[1]Division of General Internal Medicine, St. Michael's Hospital, Toronto, Ont.; [2]Department of Medicine, University of Toronto, Toronto, Ont.; [3]Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Ont.; [4]Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Ont.; [5]Women's College Hospital Institute for Health Systems Solutions and Virtual Care, Women's College Hospital, Toronto, Ont.; [6]Baycrest Geriatric Health Care System, Toronto, Ont.; [7]Division of General Internal Medicine, University Health Network, Toronto, Ont.; [8]Trillium Health Partners, Mississauga, Ont.; [9]Department of Medicine, Mount Sinai Hospital, Toronto, Ont.; [10]Sunnybrook Health Sciences Centre, Toronto, Ont.; [11]Department of Family and Community Medicine, University of Toronto, Toronto, Ont.;

*Authors contributed equally.
‡BW, TC and AAV are joint senior authors.

Corresponding author:
Fahad Razak
E: fahad.razak@mail.utoronto.ca

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Background:

The Coronavirus 2019 (COVID-19) outbreak increases the importance of strategies to enhance urgent medical care delivery in long-term care (LTC) facilities that could potentially reduce transfers to emergency departments. The objective of this study was to model resource requirements to deliver virtual urgent medical care in LTC facilities.

Methods:

We used data from all general medicine inpatient admissions at 7 hospitals in the Greater Toronto Area over a 7.5 year time period to estimate historical patterns of hospital resource use by residents of LTC facilities. We estimated an upper bound of potentially avoidable transfers by combining data on short admissions (<= 72 hours) with historical data on the proportion of transfers from LTC that are discharged from the emergency room without admission. Regression models were used to extrapolate future resource requirements and queuing models were used to estimate physician staffing requirements to perform virtual assessments.

Results:

Short admissions constituted 19.9% of all admissions from LTC, and 99.6% of these patients received laboratory testing, 86.9% received plain radiography, 41.2% received computed tomography, and 80.2% received intravenous medications. If all potentially avoidable LTC admissions and emergency department transfers were diverted to outpatient care, the average weekly outpatient imaging demand per hospital would be 3 ultrasounds, 12 CT scans, and 24 radiographs per week. The average daily volume of urgent medical virtual assessments would range from 2.0 to 5.8 across per hospital. We estimate an upper bound of 60% of all transfers being avoidable, more than >12,000 per year in Ontario. A single centralized virtual assessment centre staffed by 2-3 physicians would provide similar efficiency (measured by waiting time for physician assessment) to 7 separate centres staffed by 1 physician each.

Interpretation:

Should reducing the transfer of LTC residents to hospital during a pandemic be deemed high priority, key resources to support front line care teams at LTC would likely include rapid access to outpatient diagnostic imaging, within facility access to laboratory services and IV medication, and virtual physician consultation, among other needs such as skilled nursing. The results of this study can inform efforts the deliver urgent medical care in LTC facilities in light of a potential surge in COVID-19 cases.

Introduction

Reducing transfer of Long-Term Care (LTC) facility residents to acute care hospitals has been a focus of quality improvement efforts for many years.(1) Coronavirus disease 2019 (COVID-19) has only sharpened this focus. COVID-19 affects older adults more severely, especially those with chronic medical conditions,(2) making LTC facilities an especially vulnerable setting for widespread transmission. Early examples of COVID-19 outbreaks in LTC have resulted from within-facility spread among residents and healthcare staff, with high resident fatality rates.(3) Nosocomial spread of COVID-19 from hospitals to LTC facilities could have dire consequences.(3) A rapidly deployable strategy to safely reduce the frequency of transfers from LTC to hospital emergency departments may reduce the risk of nosocomial exposure and improved capacity in emergency departments and hospital wards.(4, 5) This would benefit patients and the health system more broadly. The provision of urgent medical and diagnostic services in the community setting could be an important component of a broader strategy to reduce transfers from LTC to hospitals.

The objective of this paper is to support rapid deployment of creative interventions to deliver urgent medical care to LTC residents outside hospital settings, in the context of a widespread COVID-19 outbreak. We used a cohort of general medicine admissions across seven large hospitals in Ontario to describe: 1) Patients admitted to hospital from LTC, and the subset of these patients that may have potentially 'avoidable' admissions; 2) The use of resources such as laboratory testing, imaging and intravenous (IV) medication among these patients. We then modelled the resources required for the delivery of urgent medical care in an outpatient setting: virtual specialty physician consultation and rapid access to outpatient diagnostic services.

Methods

Study Design, Population and Data Sources

This analysis uses multicentre hospital data from the General Medicine Inpatient Initiative (GEMINI). We have previously described GEMINI in detail.(6) Briefly, the GEMINI cohort comprises all patients admitted to or discharged from the General Internal Medicine (GIM) service at seven participating hospitals, including five academic institutions and two community teaching hospitals, in Toronto and Mississauga, Ontario, Canada between April 1, 2010 and October 31, 2017. All participating hospitals are publicly funded, operate independently, and provide tertiary and/or quaternary care. In this study, we included all patients whose emergency department visit resulted in an admission. We did not include elective/planned hospital admissions or inter-hospital transfers. All patients were followed in hospital until death or discharge.

We collected clinical and demographic characteristics from each hospital's electronic information systems and health administrative databases as reported for the Discharge Abstract Database and National Ambulatory Care Reporting System of the Canadian Institute for Health Information (CIHI).(7, 8) Each inpatient and emergency department individual-level record included age, sex, place of residence at time of admission and discharge, most responsible discharge diagnosis, diagnostic and therapeutic procedures, laboratory (biochemistry, hematology and microbiology) test results, radiology test results, blood transfusions, medications, and intensive care unit admissions. All data were linked using unique identifiers and a subset of the data demonstrated 98-100% accuracy compared to chart review.(9)

Ethics

Each participating hospital obtained approval from its research ethics board and authorized the use of data under a waiver of patient consent given the large retrospective nature of the data and the limited risk to an individual patient.

Measures

We identified all patients who were admitted from or discharged to LTC facilities using the institution number developed by the Ministry of Health and Long-Term Care Master Numbering System in our administrative data.(10) LTC facilities included nursing homes and complex continuing care facilities but not rehabilitation hospitals. To increase our sensitivity in detecting patients who were admitted from LTC we considered patients who had an institution number code in either their 'institution to' or 'institution from' field given it is unusual in Ontario for hospitalized patients to be newly discharged to LTC.

We included the following patient and situational characteristics: age; sex; Charlson Comorbidity Index score calculated using the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA);(11) Laboratory-based Acute Physiology Score (LAPS), which is a validated predictor of inpatient mortality risk;(12) admission to GIM at participating GEMINI hospitals in the 30 previous days; admission day and time; triage day and time; and calendar year of admission.

For each LTC-related admission, patient outcomes and resource utilization during hospitalization were characterized by examining the use of imaging procedures (radiography, computed tomography (CT), ultrasound, magnetic resonance imaging (MRI) and interventional radiology procedure), erythrocyte transfusion, and endoscopy.(13) We identified patients who had special care unit admission (Intensive Care or 'Step-Up" Units), in-hospital death and readmission to GIM at participating GEMINI hospitals within 30 days of discharge. Furthermore, we reported most responsible discharge diagnosis after grouping ICD-10-CA main diagnoses codes according to the Clinical Classifications Software.(14)

We defined hospital length of stay (LOS) as the time from admission to discharge and emergency department wait time as the time from triage by nursing staff to disposition. There are no universally accepted definitions of 'avoidable' admissions.(1) Although this is challenging to determine observationally, it is easier to estimate for patients who come from LTC than for the general patient population. This is because hospital LOS for patients coming from LTC is not prolonged by "disposition planning", as patients already have a clear discharge destination: their LTC facility. Therefore, in LTC patients the hospital LOS would be expected to correlate well with severity of illness and the need for hospital resources. We focused here on patients with admissions <= 72 hours (potentially avoidable) versus more than 72 hours (unlikely avoidable) based on previous definitions in the literature.(15)

Statistical Analysis

Descriptive statistics were summarized using proportions, means with standard deviations (SDs) and medians with interquartile ranges (IQRs) where appropriate. For patients who were admitted from or discharged to LTC, we compared patient characteristics, situational factors and hospital resources utilization with standardized mean differences (SMDs), and consider a value >0.1 as a sign of meaningful difference between groups.(16) Beyond testing for significance, SMDs also estimate the magnitude of the difference between groups.

Modelling Staffing and Resource Requirements for a Virtual Care Strategy

We estimated outpatient diagnostic imaging and physician staffing requirements for a virtual care strategy to reduce transfer from LTC to hospital. In order to be conservative in our estimates (i.e. to estimate the upper bound of resources that would be required, based on historical patterns of use), we modeled resource use by assuming that all "potentially avoidable" transfers from LTC could be diverted. We considered potentially avoidable transfers to include: 1) All patients who present to the emergency department and are returned to LTC without admission, which is approximately 50% of all LTC transfers based on published estimates in Ontario; (17) and 2) Patients who are admitted <= 72 hours (20% of the admitted sample, Table 2). It is unlikely that any virtual physician consultation strategy supported by rapid access to the additional outpatient resources we describe (diagnostic imaging, intravenous medication, etc.) would be completely successful in reducing all potentially avoidable transfers. Therefore, this model provides an upper bound on the outpatient resources required to support a virtual strategy, assuming needs are similar to historical patterns of use. Given the relative lack of reliable data regarding COVID-19-related resource demands in Canada, we have elected not to include estimates of this effect in our models. Finally, important non-physician resources that would be crucial to providing efficient and resident-centric care at LTC facilities are not modelling here. These include (but are not limited to) physiotherapists and occupational therapists, social workers, pharmacists and skilled nursing care.

Diagnostic Imaging - For each imaging modality, we determined the total number of scans across the seven hospitals in each year from 2011 to 2016 for patients with LOS less than 72 hours. We multiplied this number by the time per scan, which was an estimated amount that was comprised of patient setup time, actual imaging time, and time to prepare the room for the next patient. This estimate varied by modality and body part imaged, and was based on expert opinion (from a hospital-based radiologist) given the lack of published data around such times (S-Table 1). A linear regression was fit to the annual imaging volume and extrapolated to estimate an imaging volume for 2020. We also report a prediction interval, which provides a conservative estimate of uncertainty about the actual volume rather than a confidence interval.(18) The weekly total for each modality was apportioned into hospital-specific estimates using the average proportion of imaging volume (in hours) from each hospital over 2011-2016.

We estimated diagnostic imaging required for patients with LOS less than 72 hours based on GEMINI, and extrapolated these numbers to those who had an emergency department visit but were not admitted.

Length of Stay Modelling - Similar to our approach with diagnostic imaging, to estimate total LOS, yearly LOS (instead of yearly scan time) was used for as the regression dependent variable. Hospital-specific proportions were also derived.

Physician Virtual Assessment Centre Staffing - We developed queuing models to estimate how many physicians would be needed to staff a virtual assessment centre to serve the potential divertible population of each hospital.(19) We focused on physicians in this model given an underlying assumption that acute physician assessment is one of the main objectives of sending a LTC resident to an emergency department. There may be alternate support strategies that do not focus on physician assessments as a starting point (for example, using an acute care nurse as the starting point of an assessment).

Starting with triage times of patients who arrived at each hospital, we subtracted a random amount drawn from a uniform distribution between 60 to 120 minutes to estimate the original 911 call time. For each year from 2011 to 2016, we then binned the call times into one-hour increments, and scaled the distribution so the daily call volume that could be expected by a virtual centre equals twice the average historical daily call volume for admitted patients (based on historical estimate that 50% of patients are not admitted).(17) To estimate average daily call volume for 2020, we extrapolated via linear regression the average daily call volume over all hospitals and used hospital-specific proportions based on total call volume. We report a confidence interval since we are reporting on the average call volume. The distribution of estimated call arrival times was similar for each hospital (data not shown) and S-Figure 1 shows the normalized distribution over all hospitals.

We assumed a Poisson distribution for arrivals and used thinning to simulate the nonstationary arrival process.(20) Based on expert opinion from internal medicine physicians who have provided virtual care assessment to LTC residents, we assumed the duration of each assessment followed a triangle distribution with a center at 45 minutes and minimum/maximum values at 15/75 minutes. We simulated 1000 days of operating the centre 24 hours a day and calculated the distribution of wait times (time from call until physician assessment begins) as a function of a fixed staffing level throughout the entire day. We conducted this queuing analysis for each hospital separately, based on their individual volumes. To determine the relationship between call volume and waiting time for different staffing levels, we repeated the simulation for different levels of call volume.

Results

The GEMINI cohort includes 245559 patients admitted to or discharged from GIM between April 1, 2010 and October 31, 2017, of which 235375 (96%) were admitted from the emergency department and are the focus of this analysis. LTC residents accounted for 13.5% of all admissions to GIM (Table 1).

Comparison between patients admitted from LTC versus all other admissions (Table 1).

Compared to other admitted patients, those from LTC were older (85 versus 70 years), had higher medical acuity (LAPS value 25.2 versus 19.3), higher Charlson Comorbidity Index (score 2 or more in 62.8 % versus 40.9%). A greater percentage of patients admitted from LTC had a GIM admission at a GEMINI hospital in the prior 30 days compared to non-LTC admissions (13.2% versus 10.0%).

Resource Use and Outcomes for Patients from LTC with Admissions <=72 hours (Table 2)

Patients with admissions <=72 hours constituted about 20% of all admissions to GIM from LTC (4.0% for admissions < 24 hours, and 15.9% for admission 24-72 hours – S-Table 1). Nearly all patients received laboratory testing (99.6%). Among diagnostic imaging modalities, plain radiography (86.9%) and CT scan (41.2%) were the most commonly used, ultrasound was used by 11.7% of individuals, and MRI and interventional radiology were used by <2%. 85% of patients need IV medications.

The mortality rate was especially high among those with an admission of < 24 hours (22.2%, S-Table 2)

Most Common Admissions Reasons for Patients from LTC (S-Table 3)

The 5 most common discharge diagnoses of patients admitted from LTC are Urinary Tract Infection, Delirium/Dementia, Pneumonia, Aspiration and Heart Failure. Cumulatively, the top 10 discharge diagnoses account for 52.6% of admissions.

Modelling Staffing and Resource Requirements for a Virtual Care Strategy

<u>Diagnostic Imaging Requirements (S-Table 4):</u> For an average hospital, the weekly outpatient imaging demand would be 2.6 ultrasounds, 11.9 CT scans, 23.9 radiographs. Patients admitted would have required 5.7 bed-days per week per hospital.

<u>Virtual Assessment Centre Staffing (Figure 1):</u> The average daily volume of calls per hospital is estimated to range from 2.0 to 5.8 across the 7 participating hospitals (s-Table 5). With a single physician staffing a virtual care centre, the average wait time would range from 1.6 minutes assuming a daily volume of 2 calls to 403.7 minutes assuming a daily volume of 30 calls. With a single physician, the average wait time would exceed 15 minutes once the daily call volume exceeds 10 calls. With two physicians, the average wait time would remain below 16 minutes for up to 30 calls per day. The 90th percentile of the wait time with two physicians exceeded 15 minutes once the call volume exceeded 17 calls. With three physicians, the 90th percentile wait time remained below 9 minutes up to a call volume of 30.

S-Table 5 demonstrates that for the seven hospitals considered and their specific call volumes, one physician for each hospital (i.e. seven physicians working simultaneously across the seven hospitals) would maintain a 90th percentile wait time below 27.1 minutes. However, if the call volume of these seven hospitals was pooled, roughly 26.9 calls per day, then two physicians at a single virtual assessment centre would achieve a 90th percentile wait time of 38.1 minutes, while three physicians at a single virtual assessment centre would achieve a 90th percentile wait time of 1.6 minutes. (as per Figure 1, S-Table 6).

The busiest 12 hours of the day (i.e., 7AM – 7PM) accounted for 73.4% of the daily call volume (S-Figure 1).

Ontario-Wide Impact on Transfers to Emergency Room and In-Hospital Bed-Days (Appendix 1)

The upper-bound estimate of the impact of an Ontario-wide program of virtual physician consultation to reduce transfer of LTC residents to hospital is an annual reduction 12,231 transfers and 3832 bed-days based on historical data (Appendix 1).

Discussion

This paper offers two major insights about the diagnostic and therapeutic resources and physician staffing volumes that may be required to support the delivery of urgent medical care to LTC facilities to reduce transfer to hospital. First, the outpatient diagnostic imaging resources required are likely on a scale that is achievable using existing outpatient services (3 ultrasounds, 12 CT scans, 24 radiographs per hospital per week). Second, if a virtual physician consultation service were established, consolidation to centralized hubs would greatly reduce the number of physicians required to staff these services at any one time, while still having the capacity to maintain safe response times. A centralized hub with 2-3 physicians would provide equally efficient service as decentralized hubs with 7 physicians (1 per hospital) in our sample. Finally, the annual system impact at scale on the Province of Ontario would have an upper bound of greater than 12,000 fewer transfers to emergency room and reduction of more than 3800 bed-days if the intervention was successful.

For an individual resident of LTC, avoiding a transfer to hospital may reduce their risk of COVID-19 exposure during assessment and transportation by emergency medical services, in emergency departments or on hospitals wards. Such nosocomial exposure has been a noted mechanism of spread for other respiratory viral pathogens such as seasonal influenza or SARS.(4, 5) Our data demonstrate that LTC residents have higher 30-day readmission rates than typical general medicine patients. This is particularly relevant given approximately 80% of COVID 19 spread occurs through asymptomatic carriers(21). Through nososcomial exposure, an LTC resident could become an asymptomatic COVID-19 vector and precipitate an outbreak among the other residents of their facility. More generally, reducing avoidable transfers from LTC to hospital limits the risk of hospital-related iatrogenic harm or adverse events when patients are transferred back to LTC.(22, 23)

Reducing hospital transfers of LTC residents may also be an important strategy to protect emergency department and ward capacity if there is a surge in COVID-19 related admissions. Our data demonstrate that residents of LTC have higher readmission rates within 30 days than typical general medicine patients. Furthermore, COVID-19 outbreaks in LTC could also become barriers to transfer back to a patient’s home facility.

Our data suggest that nearly all patients admitted to hospital from LTC require laboratory testing and more than 85% require IV medication. We therefore did not model the requirement for these services, as any urgent medical care would likely require on-site phlebotomy and the ability to deliver IV medication. Moreover, to deliver high quality urgent medical care in LTC, local primary care and nursing would be essential components of care. GEMINI does not have information on other elements of care, such as comprehensive primary care, or acute nursing care, but these would be essential to deliver urgent medical care and necessary elements of any strategy to limit the transfer of LTC residents to hospital. In addition, given ~25% of admissions <= 72 hours have a cardiorespiratory etiology (S-Table 3), on-site electrocardiograms and supplemental oxygen would be essential components of diagnosis and management.

We focused our modelling on diagnostic imaging, as it can be crucial to the assessment process for many patients requiring acute care but may not be readily portable and therefore is unlikely to be accessible on-site at most LTC facilities. Even in an ambitious scenario wherein virtual care successfully prevented all transfers of patients who would not have been admitted or would have short admissions (about 60% of total transfers between these two groups), the weekly estimates for outpatient radiographs (23.9 per hospital) and CT scans (11.9 per hospital) are likely achievable if resources were marshalled. Facilitating rapid access to these services through a route other than the emergency department is an important component of innovative models of outpatient urgent medical care.

Our model suggests that a single virtual consultation service physician for each hospital would be able to respond to typical calls from LTC facilities within an acceptable time frame (< 15 minutes) for up to 10 calls per day – a number that is higher than typical transfer volumes. However, economies of scale can result from aggregating virtual calls. For example, in the seven hospitals in GEMINI, a consolidated virtual service staffed by just 2-3 physicians at any one time achieved the same 90th percentile wait time as seven individual physicians working simultaneously at each hospital.

Our model focuses on urgent medical consultation and does not account for the need for various physician and allied health specialties that would be part of a broad and fully patient-centered virtual consultation service. For example, 20% of patients admitted for <24 hours die within hospital (S-Table 2), and this highlights the likely need for palliative services in addition to general consultative services. Moreover, decisions about how to deploy virtual assessment services should consider factors other than efficiency, such as developing and leveraging institutional relationships and local partnerships to facilitate quality improvement, which may be easier with some degree of decentralization.

This study has a number of limitations. First, there is no well accepted definition of an avoidable transfer from LTC to hospital. Prior attempts to provide proxies for avoidability have used measures such as ambulatory-care sensitive conditions, low acuity admissions or short admissions.(15, 17) We provide an upper bound on total resources that may be required, but it is unlikely that all of these patients truly represent avoidable transfers. In addition, our upper bound likely also includes patients that could be treated in a non-hospital setting if appropriate resources were made available - For example, patients who only require intravenous antibiotics. Second, our models are based on admissions to general medicine whereas many transfers from LTC to hospital may be for issues like injuries requiring other types of physician or non-physician services. However, our focus was on delivering urgent medical services, which is particularly salient in the setting of COVID-19. Delivering virtual urgent medical care represents only one part of a broader strategy to enhance high quality care for residents of LTC. Third, our modeling is based on estimates of historical use. It is possible that in the setting of COVID-19 outbreaks, there will be increased demand for virtual urgent medical services to LTC facilities. Our models highlight how centralization of resources in virtual call centres might be particularly important to achieve efficiency that is needed to meet increased demand. Fourth, our modelling does not consider the technical demands (infrastructure, credentialing, etc.) that would be required to support a virtual care service, and these represent important process barriers to a rapid implementation of a virtual consultation service. Such factors may also influence decisions regarding centralization versus decentralization. Fifth, our models use resource demands from patients with short admission to extrapolate to those who are transferred from LTC to emergency departments but not admitted. This likely represent an over-estimate of the resources required, especially given difference in primary referral reason for patients who are admitted versus not-admitted.(17) This increases the likelihood that our estimates represent an upper-bound. Sixth, we do not wish to imply that virtual physician assessments replace the work of bed-side care which importantly would entirely be dependent on staff at the LTC facility. This paper does not model the increase in staffing resources at the LTC facility that would be required to support virtual care assessments and the facilitate implementation of treatment recommendations.

In conclusion, our paper models the resources required if a virtual strategy for urgent medical care was adopted to reduce transfer of patients from LTC to hospital. These results are informing a rapidly evolving pilot in Ontario, Canada to provide virtual consultation service to

LTC facilities, and these findings may have application across various jurisdictions in light of a potential surge in COVID-19 cases.

	Overall	Admitted from LTC	Not Admitted From LTC
number	235375	31869	203506
admission to GIM from ER (%)	209159 (88.9)	27673 (86.8)	181486 (89.2)
age (median [IQR])	72.00 [57.00, 83.00]	85.00 [77.00, 90.00]	70.00 [54.00, 81.00]
LAPS (mean (SD))	20.11 (17.23)	25.23 (18.08)	19.31 (16.95)
time in ER (median [IQR])	14.67 [9.90, 23.65]	16.00 [10.22, 26.00]	14.38 [9.80, 23.10]
Female (%)	117757 (50.0)	18722 (58.7)	99035 (48.7)
Charlson Comorbidity Index >=2	103243 (43.9)	20007 (62.8)	83236 (40.9)
weekday admission (%)	175121 (74.4)	23385 (73.4)	151736 (74.6)
daytime admission (%)	54136 (23.0)	7657 (24.0)	46479 (22.8)
weekday triage (%)	177298 (75.3)	23674 (74.3)	153624 (75.5)
daytime triage (%)	129744 (55.1)	18207 (57.1)	111537 (54.8)
admitted to GIM in previous 30 days (%)	24014 (10.4)	4146 (13.2)	19868 (10.0)

Table 1 – Descriptive characteristics of patients admitted or discharge from General Internal Medicine.

	Overall	LOS <=72 hours	LOS >72 hours	SMD
number	31869	6334	25535	
Length of Stay (median [IQR])	7.12 [3.65, 15.38]	1.88 [1.25, 2.57]	9.44 [5.55, 18.64]	0.610
IV Medication (%)	27690 (86.9)	5083 (80.2)	22607 (88.5)	0.230
Laboratory Testing (%)	31831 (99.9)	6311 (99.6)	25520 (99.9)	0.066
Any X-Ray Imaging(%)	29436 (92.4)	5504 (86.9)	23932 (93.7)	0.232
Any CT-Scan (%)	18234 (57.2)	2609 (41.2)	15625 (61.2)	0.408
Any Ultrasound (%)	9129 (28.6)	741 (11.7)	8388 (32.8)	0.526
Any MRI (%)	2343 (7.4)	65 (1.0)	2278 (8.9)	0.369
Use of Interventional Radiology (%)	3137 (9.8)	113 (1.8)	3024 (11.8)	0.407
RBC Transfusion (%)	2847 (8.9)	272 (4.3)	2575 (10.1)	0.226
Endoscopy (%)	1489 (4.7)	136 (2.1)	1353 (5.3)	0.167
ICU Admission (%)	2716 (8.5)	144 (2.3)	2572 (10.1)	0.328
Death (%)	2710 (8.5)	772 (12.2)	1938 (7.6)	0.155
Readmission to GIM in 30 days (%)	3525 (12.2)	695 (12.6)	2830 (12.1)	0.014

Table 2 – Descriptive characteristics of patients from admitted from long term care, stratified by duration of admission.

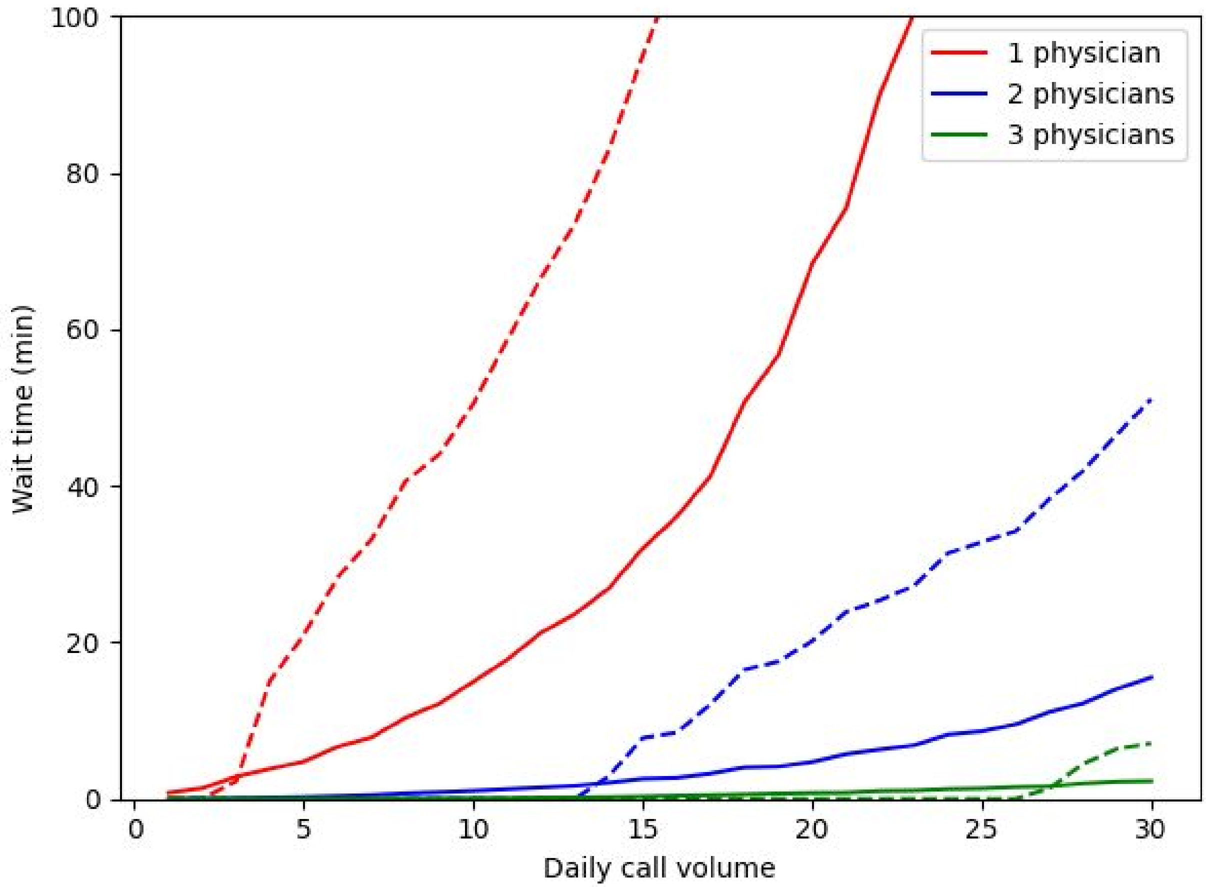


Figure 1 – Average and 90th percentile waiting time by daily call volume for virtual assessment centres staffed by 1, 2, or 3 physicians 24 hours a day. Solid line represents average and dashed line represents 90th percentile waiting time.

	Scan time (min)	Turnover (min)
US – abdomen	30	25
US - dvt	10	25
US - pelvis	30	25
US - combination	50	25
CT	5	25
X-Ray	5	25

Supplement Table 1 – Estimated scan and turnover times (patient loading, cleaning, etc.) for various imaging modalities. Numbers based on expert opinion.

	Overall	LOS <24 hours	LOS 24-72 hours	LOS >72 hours	SMD
n	31869	1282	5052	25535	
Length of Stay (median [IQR])	7.12 [3.65, 15.38]	0.62 [0.44, 0.79]	2.23 [1.67, 2.65]	9.44 [5.55, 18.64]	1.625
IV Medication (%)	27690 (86.9)	908 (70.8)	4175 (82.6)	22607 (88.5)	0.301
Laboratory Testing (%)	31831 (99.9)	1270 (99.1)	5041 (99.8)	25520 (99.9)	0.088
Any X-Ray Imaging(%)	29436 (92.4)	1065 (83.1)	4439 (87.9)	23932 (93.7)	0.226
Any CT-Scan (%)	18234 (57.2)	471 (36.7)	2138 (42.3)	15625 (61.2)	0.334
Any Ultrasound (%)	9129 (28.6)	63 (4.9)	678 (13.4)	8388 (32.8)	0.512
Any MRI (%)	2343 (7.4)	5 (0.4)	60 (1.2)	2278 (8.9)	0.287
Use of Interventional Radiology (%)	3137 (9.8)	11 (0.9)	102 (2.0)	3024 (11.8)	0.318
RBC Transfusion (%)	2847 (8.9)	38 (3.0)	234 (4.6)	2575 (10.1)	0.196
Endoscopy (%)	1489 (4.7)	13 (1.0)	123 (2.4)	1353 (5.3)	0.168
ICU Admission (%)	2716 (8.5)	25 (2.0)	119 (2.4)	2572 (10.1)	0.233
Death (%)	2710 (8.5)	285 (22.2)	487 (9.6)	1938 (7.6)	0.281
Readmission to GIM in 30 days (%)	3525 (12.2)	119 (12.0)	576 (12.7)	2830 (12.1)	0.015

Supplement Table 2 – Descriptive characteristics of patients admitted from long term care.

	Overall N=31869	LOS <=72 hours N=6334	LOS >72 hours N=25535	SMD
Urinary Tract Infection (%)	2445 (7.7)	539 (8.5)	1906 (7.5)	0.039
Delirium, Dementia (%)	2403 (7.5)	295 (4.7)	2108 (8.3)	0.147
Pneumonia (%)	2253 (7.1)	538 (8.5)	1715 (6.7)	0.067
Aspiration Pneumonitis (%)	1922 (6.0)	502 (7.9)	1420 (5.6)	0.094
Heart Failure (%)	1874 (5.9)	296 (4.7)	1578 (6.2)	0.067
COPD (%)	1504 (4.7)	270 (4.3)	1234 (4.8)	0.027
Stroke (%)	1473 (4.6)	300 (4.7)	1173 (4.6)	0.007
Fluid and Electrolyte Disorders (%)	1296 (4.1)	135 (2.1)	1161 (4.5)	0.135
Palliative and other care(%)	871 (2.7)	227 (3.6)	644 (2.5)	0.062
GI Hemorrhage (%)	740 (2.3)	130 (2.1)	610 (2.4)	0.023

Supplement Table 3 - 10 most frequent admission discharge diagnoses for patients admitted from long term care.

	US		CT		X-ray		LOS (days/week)
	scans/week	hrs/week	scans/week	hrs/week	scans/week	hrs/week	
Site A	1.5 [1, 2.1]	1.4 [0.9, 1.9]	11 [8.6, 13.3]	5.5 [4.3, 6.7]	26.3 [23.2, 29.3]	13.1 [11.6, 14.6]	5.9 [5.4, 6.5]
Site B	1.9 [1.2, 2.6]	1.7 [1.1, 2.3]	16.2 [12.7, 19.7]	8.1 [6.3, 9.9]	30.3 [26.8, 33.8]	15.2 [13.4, 16.9]	7.1 [6.5, 7.8]
Site C	0.9 [0.6, 1.3]	0.8 [0.5, 1.1]	6.2 [4.8, 7.5]	3.1 [2.4, 3.8]	13.3 [11.8, 14.8]	6.7 [5.9, 7.4]	3.4 [3.0, 3.7]
Site D	2.7 [1.7, 3.7]	2.4 [1.5, 3.3]	8.7 [6.8, 10.6]	4.4 [3.4, 5.3]	21.3 [18.8, 23.8]	10.7 [9.4, 11.9]	4.6 [4.2, 5.0]
Site E	3.4 [2.2, 4.6]	3.1 [1.9, 4.2]	12.8 [10, 15.6]	6.4 [5, 7.8]	23.5 [20.8, 26.3]	11.8 [10.4, 13.1]	6.3 [5.7, 6.9]
Site F	2.3 [1.5, 3.2]	2.1 [1.3, 2.8]	8.3 [6.5, 10.2]	4.2 [3.3, 5.1]	16.2 [14.4, 18.1]	8.1 [7.2, 9.1]	3.8 [3.5, 4.2]
Site G	3.2 [2, 4.4]	2.9 [1.8, 3.9]	13.5 [10.6, 16.4]	6.7 [5.3, 8.2]	26.8 [23.7, 29.9]	13.4 [11.8, 14.9]	6.2 [5.7, 6.8]
Avg	2.6 [1.7, 3.5]	2.3 [1.5, 3.2]	11.9 [9.3, 14.5]	5.9 [4.6, 7.2]	23.9 [21.2, 26.7]	12 [10.6, 13.3]	5.7 [5.1, 6.2]

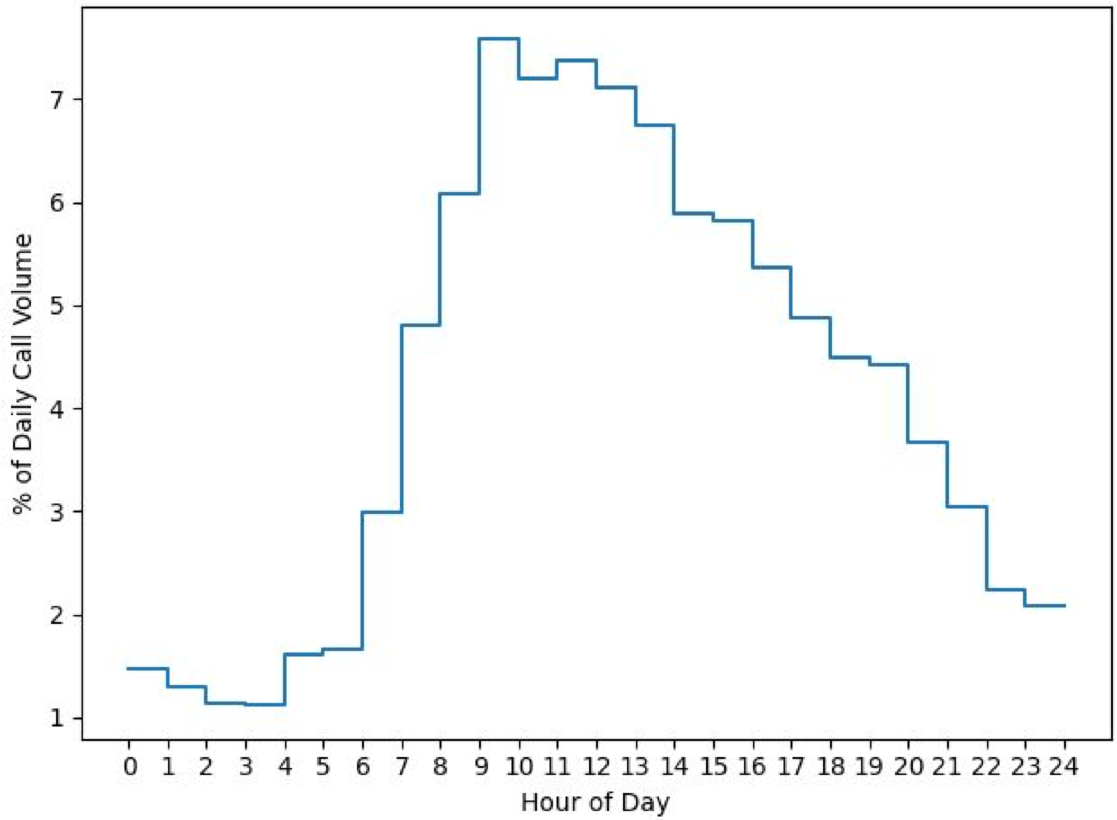
Supplement Table 4– Weekly number of diagnostic scans, total diagnostic scan time, and LOS days diverted with an assumption that of all patients presenting to the emergency room department, 60% may be avoidable. The estimate of 60% avoidable is based on a prior literature that ~50% of all transfers are not admitted,(17) and results from Table 2 that 10% of all transfers (20% of those admitted) are admitted for <= 72 hours. 95% prediction intervals in parentheses. Each site represents one acute care hospital in GEMINI.

	Daily Call Volume	Avg wait time (min)	90th percentile of wait time (min)
Site A	3.5 [3, 4.1]	3.3 [3.2, 3.4]	8.7 [7.8, 9.5]
Site B	4.4 [3.7, 5.0]	4.2 [4.1, 4.3]	17.1 [16.6, 17.6]
Site C	2.0 [1.7, 2.3]	1.7 [1.6, 1.8]	0.0 [0.0, 0.0]
Site D	4.0 [3.5, 4.6]	3.8 [3.8, 3.9]	14.6 [13.8, 15.4]
Site E	5.8 [4.9, 6.6]	6.1 [6.0, 6.2]	27.1 [26.7, 27.6]
Site F	2.8 [2.4, 3.2]	2.5 [2.4, 2.5]	0.3 [0.0, 0.6]
Site G	4.4 [3.8, 5.1]	4.4 [4.3, 4.5]	18.0 [17.4, 18.6]

Supplement Table 5 – Average volume and wait time characteristics of a virtual assessment centre with a single physician for each hospital. Simulation of 1000 days replicated 30 times to determine 95% empirical confidence intervals. Each site represents one acute care hospital in GEMINI.

	Avg daily volume	# Physician staff	Ave wait time (min)	90th percentile (min)
All Sites	26.9 [23, 30.9]	1	178 [175.8, 180.3]	406.1 [400.3, 412]
		2	10.8 [10.6, 10.9]	38.1 [37.7, 38.6]
		3	1.7 [1.6, 1.7]	1.6 [1.4, 1.8]

Supplement Table 6 – Average wait time characteristics of a centralized hub virtual assessment service under staffing models of 1,2 or 3 physicians working simultaneously. Estimate based on estimated daily call volume (26.9) across 7 GEMINI hospitals.



Supplemental Figure 1 – Normalized distribution of daily call volume to a virtual assessment centre.

Appendix 1: Ontario-Wide Impact on Transfers to Emergency Room and In-Hospital Bed-Days

Transfers to Emergency Room:

1. We assume an upper bound of avoidable transfers of 60% of all transfers
    - ~50% of patients transferred to hospital are not admitted based on historical data(17)
    - ~10% admission for are for <= 72hours based on GEMINI data (Table 2)
    - We add these two groups to arrive at ~60% of transfers being potentially avoidable
2. Historical data for Ontario from 2010 estimates that there were 71,780 residents of LTC and 28.4% were transferred to hospital.(24)
3. Based on, this we estimated 12,231 transfer to hospital
    - 71,780 residents in LTC * 28.4% transfer rate * 60% potentially avoidable = 12,231 potentially avoidable transfers

Hospital Bed Days (for admitted patients):

1. We estimated 3832 annual bed-days that are potentially avoidable
    - 71780 patients * 28.4% transfer rate * 50% admission rate * 20% admitted for <=72 hours * median LOS 1.88 (table 2) = 3832.5 bed days

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