Trends in General Internal Medicine Patient and Care Complexity from 2017 to 2022 across 21 Hospitals

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Abstract

Background: There is ongoing uncertainty about whether hospital inpatients have become more complex over time, and how this might contribute to strained hospital resources. We examined measures of patient and care complexity for General Internal Medicine (GIM) inpatients over a 7-year period.

Methods: This retrospective cohort study used individual-level administrative and clinical data for GIM hospitalizations at 21 Ontario hospitals between April 2015–June 2022. Complexity measures included patient characteristics (e.g., advance age), patient outcomes (e.g., in-hospital mortality), and resource use

(e.g., imaging). Hospitalizations were categorized into complex and non-complex categories and generalized linear mixed-effects models were used to estimate adjusted rate ratios, representing the relative change in the number of monthly admissions in each year for each category compared to 2015-2016.

Results: The cohort included 687,512 hospitalizations (median [IQR] age, 73 [57-84] years; 50% female). The volume of admissions grew by 17%, from 103,851 in 2015-16 to 121,103 in 2021-22. There was a consistent increase in the use of radiology tests, particularly driven by greater use of CT scans (49% of hospitalizations in 2015-16, 61% in 2021-22, adjusted rate ratio 1.45 [CI, 1.40-1.50]) and MRI scans (11% in 2015-16, 14% in 2021-22, adjusted rate ratio 1.46 [CI, 1.39-1.54]). Other patient characteristics, processes of care, and outcomes did not consistently change across the study period. The COVID-19 pandemic period (April 2020-June 2022) was associated with increased complexity with respect to hospital length-of-stay, in-hospital mortality, laboratory testing, and costs of care.

Interpretation: GIM admission volume increased over the study period, but patient complexity as measured by the metrics considered here did not show consistent increases. The rising intensity of imaging use without evident changes in patient characteristics or short-term outcomes warrants further investigation.

Introduction

Patient complexity is often described using demographic factors, multimorbidity, polypharmacy, psychosocial challenges, and social determinants of health.[1] Patients with higher complexity tend to experience poorer health outcomes,[2,3] higher health care costs,[4,5] and lower satisfaction with their care.[6,7] For clinicians, managing complex patients may contribute to increased workload and burnout,[1] while placing significant demands on hospital capacity.[8]

There is ongoing debate about whether hospital inpatients have become more complex over time, and whether this trend contributes to strained hospital capacity and rising costs. Understanding these trends is important for health system planning because rising hospital resource needs may be driven by increasing admission volume, increasing patient complexity, or both. In addition, different dimensions of complexity, such as increases in comorbidity versus diagnostic intensity, may require different responses. Population aging, the growing burden of chronic disease, and increasing polypharmacy are all believed to contribute to rising patient complexity.[9] At the same time, advances in medical technology, societal challenges such as substance use and homelessness, and the disruptions caused by the COVID-19 pandemic may have further altered the clinical profile of hospitalized patients. However, empirical evidence on long-term trends in patient complexity across multiple hospitals remains limited. Prior studies have often been restricted to a single center,[10,11] or used narrow definitions of complexity.[12–14] Comprehensive, population-level analyses, such as a study in the Canadian province of British Columbia (BC),[15] have been limited to complexity measures captured in health administrative data. The BC study[15] found that patient complexity increased from 2002-2017, predating the COVID-19 pandemic. It focused on a broad inpatient population and did not delineate trends among general internal medicine (GIM) patients specifically. GIM services care for older, multimorbid adults, making them a clinically important setting in which to study temporal trends in inpatient complexity. Additionally, there remains an opportunity to better examine in-hospital dimensions of complexity, such as laboratory-based acuity scores and use of diagnostic testing, because the prior literature relied on administrative data.

We used electronic health records and administrative data from 21 hospitals in Ontario, Canada, to describe trends in GIM inpatient complexity over a 7-year period from 2015 to 2022. In our study hospitals, GIM patients represent approximately 40% of emergency admissions and nearly 25% of hospital bed-days.[16] We investigated changes in both patient characteristics and resource use, including diagnostic testing and medication prescribing, and assessed changes related to the COVID-19 pandemic.

Methods

Study Design and Setting

We conducted a retrospective cohort study using data from 21 hospitals in Ontario, Canada that are part of the GEMINI hospital research network. Our study received ethics approval from the University of Toronto and from all participating hospitals through Clinical Trials Ontario with Unity Health Ontario as the Research Ethics Board (REB) of Record. These 21 hospitals (See **eTable 1**) are large urban and suburban academic and community hospitals and collectively care for approximately 40-50% of GIM inpatients in Ontario. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Data

We used de-deidentified, individual-level data from the GEMINI dataset. GEMINI collects administrative and clinical data from hospital information systems with 98-100% accuracy of selected data elements compared to manual review.[16–18] Administrative data include the elements recorded in the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD); demographic information; clinical characteristics including Charlson Comorbidity Index (CCI) scores and individual Charlson conditions (see **eTable 2**); hospital frailty risk score; [24] vital signs (see **eTable 3**); the modified Laboratory-based Acute Physiology Score (mLAPS)[19] calculated within 24 hours of admission; hospitalization details; resource utilization (see **eTable 4**); Health-Based Allocation Model Inpatient Group (HIG) interventions[20] (see **eTable 5**); intensive care unit (ICU) use (including a range of units reported to CIHI as "special care units"); and outcomes such as 30-day readmissions, in-hospital mortality, and length of stay (LOS) in an Alternate Level of Care [21] (ALC).

We started with the 32 hospitals that provide GIM care in GEMINI. Eleven hospitals were excluded because they were missing all patient data for portions of the study period, leaving 21 hospitals for the analysis. Imaging-related data, including radiographs, CT scans, MRIs, and ultrasounds, were available from 15 hospitals; lab tests were available at 16 hospitals; and medication data was available for 10 hospitals. All other measures were available for the 21 hospitals.

Study population

We included all completed hospital admissions for patients admitted to or discharged from a GIM service from April 1, 2015, to June 30, 2022. We used hospitalizations as the unit of analysis. No other exclusion criteria was applied. Patients were followed from the date of hospital admission to the latest of either in-hospital death, hospital discharge, or 30-day readmission to a hospital within GEMINI.

Exposure

Passage of time (7-year study interval).

Measures of patient complexity (outcomes)

We used measures of patient complexity consistent with those previously reported based on administrative data[15], and added measures based on the clinical and scientific judgment of the study team (**Table 1**). For clarity of presentation, we grouped the complexity measures into *patient characteristics*, *patient outcomes*, and *resource use,* recognizing that these are interrelated concepts and the categories are not meant to be entirely conceptually distinct.

Patient characteristics were defined as measures reflecting the patient's health status and clinical complexity. These measures included age, Charlson Comorbidity Index (CCI), number of diagnoses, and mLAPS[23] (ranging between 0 to 231).

Patient outcomes were defined as measures reflecting the severity and clinical course of hospitalization. These included length of stay (LOS), ICU admission, 30-day readmission, and in-hospital death.

Resource use was defined using measures reflecting the intensity of resource use during hospitalization including laboratory tests, medical imaging (interventional radiology, radiographs, MRI, ultrasound, and CT scans), blood transfusions, medication orders, and adjusted cost. Adjusted costs were calculated by multiplying the Resource Intensity Weight (RIW) for each hospital admission by the CIHI cost of a standard hospital stay for the corresponding year[25] and adjusted for inflation using the Healthcare Consumer Price Index (CPI). Adjusted cost data was available between January 2016 and December 2021.

We classified hospitalizations into binary "complex" and "non-complex" categories for each complexity measure, based on prior literature and the clinical and scientific expertise of the study team. For binary measures (e.g., in-hospital death and readmission within 30 days), occurrence of the event was considered "complex". For non-binary measures (e.g., LOS and CCI score) we categorized based on clinically plausible thresholds taken from the BC study[15] and for measures not included in that study, the 90th percentile of the measure among all hospitalizations was used; see **Table 1**. To assess whether findings depended on threshold choices, we repeated the analyses using more granular categorizations of the measures; see Statistical analysis.

Each measure of complexity was analyzed separately. Each hospital encounter was categorized as "complex" or "non-complex" based on each individual measure, allowing us to study different dimensions of complexity. Thus, the same encounter could be categorized as complex on some measures and non-complex on others.

Statistical analysis

We descriptively summarized patient characteristics by fiscal year. In addition to the main complexity measures, the descriptive summaries included the hospital frailty risk score[24] (ranging between 1 to 9), and the National Early Warning Score (NEWS[22]). The frailty score was calculated exclusively for patients aged 65 years and older. NEWS was computed without incorporating the consciousness variable, as it was either unavailable or sparsely recorded across hospitals.

We aggregated our data to counts at the hospital-month-category level and fit generalized linear mixed-effects models with a negative binomial likelihood and log link[26] to examine the trends in absolute number of admissions per month across different fiscal years and for each dichotomized measure of complexity. Models included fixed effects for the calendar month, fiscal year, category of admissions (complex or non-complex), and an interaction effect between the category and fiscal year. The interaction term was

introduced to compare the adjusted growth over time in admissions between complex and non-complex admissions. Models also included a random intercept for hospitals to (a) account for the independence violation induced by nesting of patients within hospitals, and (b) so that the estimates are interpreted as within a hypothetical average hospital as opposed to marginally across all hospitals. We did not adjust for patient characteristics because the objective was to estimate temporal trends in the overall admitted population. We reported the adjusted rate ratios in each year (relative to 2015-2016) for complex and non-complex categories, representing the relative change in the number of monthly admissions in each year for each category compared to 2015-2016 (or 2017 for adjusted cost). We used the package glmmTMB in R version 4.1.3 for the estimation.[27]

To address the limitations of categorization based on arbitrary thresholds, we also examined how the distribution of non-binary complexity measures changed over time by comparing the medians and empirical distributions for the first and last fiscal years. We also repeated the regression analyses using alternative, more granular categorizations of the complexity measures (see Section 6 of Supplement 1).

As additional analyses, we examined diagnosis composition over time and the robustness of the main findings within common diagnostic groups. First, for each study year, we identified the 10 most frequent ICD-10 diagnosis codes to assess the stability of diagnosis mix over time. Second, we repeated the temporal trend analyses within subgroups defined by the 10 most common diagnosis codes in the cohort for all outcomes examined.

Results

The study cohort included 687,512 hospitalizations to 21 hospitals with median [25th-75th] age of 73 [57-84] years and 50.19% for female patients. **Table 2, eTable 2,** and **eTable 7** summarize the annual trends in the number of admissions, as well as complexity of the admitted patients in fiscal years of 2015-2016 to 2021-2022. The total number of hospitalizations increased by 16.6% from 103,851 in 2015-2016 to 121,103 in 2021-2022, with an interim decline to 112,407 in 2020-2021 during the Covid-19 pandemic. The median patient hospitalized in 2015-2016 was 73 years old, had 5 coexisting diagnoses frailty score of 4, mLAPS of 24, and NEWS score of 2. In addition, 21.8% of hospitalizations had a CCI score of 3 or greater. The median LOS was 4.67 days, 30-day readmission rate was 3.7%, and 6.9% of hospitalizations ended with death. The median hospitalization in 2015-2016 had 2 interventions, 24 medications, and 174 laboratory test results. Among all hospitalizations, 77.9% had a radiograph; 49.2% had a CT scan; 10.9% had an MRI, 30.8% had an ultrasound, 5.6% had an interventional radiology procedure, and 5.7% received an RBC transfusion.

Figures 1-3 and eFigure 3 illustrate the estimated rate ratios (relative to 2015-2016) with 95% confidence intervals (CI) for complex and non-complex admissions for patient characteristics, patient outcomes, and resource use, respectively (as defined in **Table 1**); See **eTable 8-25** for detailed results. See **eFigure 2** for illustrative examples.

Patient Characteristics

There were no consistent increases in complexity based on measured patient characteristics across the study period. The growth in the number of complex admissions based on multimorbidity (defined using either the CCI score or number of coexisting diagnoses) was significantly greater than non-complex admissions during the COVID-19 pandemic (2020-21 and 2021-22) but not prior to it. The growth in the number of

complex admissions defined by age and acuity (measured with mLAPS) was either similar to or significantly lower than non-complex admissions for all study years.

Patient Outcomes

There were no consistent increases in complexity based on measured patient outcomes across the study period. Complexity with respect to both hospital LOS and in-hospital death were significantly greater during the COVID-19 pandemic, but not in the years prior. Hospitalizations with ICU admission grew at a similar rate to hospitalizations without ICU admission across all years. Hospitalizations with 30-day readmission grew more quickly than those without readmission prior to the pandemic but were not significantly different during the pandemic.

Resource use

The number of hospital admissions with 8 (the threshold for "complex") or more radiology tests increased consistently across the study period, from 8486 (10% of all admissions) in 2015-2016 to 12245 (12% of all admissions) in 2021-2022, reflecting an adjusted rate ratio of 1.34 [CI, 1.26-1.41] in contrast to 1.14 [CI, 1.09-1.20] for non-complex patients. The median (IQR) number of radiology tests per hospitalization was 2 (1-4) in 2015-2016 and 3 (2-5) in 2021-2022. This growth was particularly driven by the increase in use of CT scans (49% of hospitalizations in 2015-2016 and 61% of hospitalizations in 2021-2022 (adjusted rate ratio 1.45 [CI, 1.40-1.50] for complex versus 0.90 [CI, 0.87-0.93] for non-complex) and MRI, which increased from 11% in 2015-2016 to 14% in 2021-2022 (adjusted rate ratio 1.46 [CI, 1.39-1.54] for complex versus 1.14 [CI, 1.09-1.19] for non-complex). Complexity increased with respect to laboratory testing and cost of hospitalization during the COVID-19 pandemic, and with respect to medication orders in 2020-2021, but not before. For other measures, there was no consistent increase in complexity over the study period.

Sensitivity and Additional Analyses

Sensitivity analyses (**eFigure 2-5** in Supplement 1) were consistent with our primary findings, demonstrating right shifts in the distributions and medians for radiology tests, CT and MRI scans, as well as LOS, lab tests and adjusted costs. The number of medications also had a notable shift to the right, consistent with the time trends that suggest numerically greater rise in the number of admissions with high medication use.

Sensitivity analyses using more granular categorizations yielded largely consistent findings, further supporting the robustness of the results to the choice of thresholds (**eFigures 7-9**). In particular, for CT and MRI scans, and medication orders higher (more complex) categories generally showed larger increases over time than the lower categories. By contrast, patient-characteristic measures showed smaller and less consistent differences across categories over time. For RBC transfusion, the number of hospitalizations receiving one transfusion increased compared to other categories that remained fairly consistent or decreased in time.

The most common ICD-10 diagnosis codes were broadly stable across study years, with substantial overlap in the top 10 diagnoses (see **eTables 26-27**). In subgroup analyses, several common diagnoses showed temporal patterns similar to those observed in the full cohort, particularly for CT scan and MRI use and total radiology testing, although the magnitude and consistency of these patterns varied across diagnoses (**eFigures 10-17**). Overall, these findings suggest that the observed temporal trends are unlikely to be explained solely by changes in diagnosis composition, but are also not uniformly present across all common conditions.

Discussion

In this large cohort study, we found that between 2015-2022, there was a consistent increase in the use of CT and MRI scans, and a possible increase in the number of medication orders, whereas proportion of complex patients with respect to patient age, CCI, acuity scores, and clinical outcomes did not consistently increase.

Naik et al.[15] found that patients have become more complex with respect to most measures of complexity. Our data are subsequent to the BC study[15] and our findings suggest that rising patient complexity has either plateaued since 2017, is not generalizable outside of BC, or is not observed within GIM. Naik et al[15] reported heterogeneity across different specialties of Medicine, Surgery, and Psychiatry and found that the greatest relative changes in complexity generally occurred among patients admitted to Psychiatry. We found continued increases in complexity measures related to physician-ordered imaging and, to a lesser extent, medications. These findings raise important questions about the drivers of greater resource use over time. However, our study cannot assess the appropriateness of imaging or medication use. Moreover, these increases were not accompanied by similarly consistent changes across patient-characteristic-based measures, including mLAPS, a laboratory-based measure of acuity not available in administrative data. Therefore, they may reflect a combination of changing diagnosis composition, evolving clinical practice, pandemic-related care patterns, and aspects of clinical complexity not fully captured by the measures available in our data. These findings warrant further investigation to determine the extent to which rising resource use reflects greater patient need versus changes in practice including possible overuse as described in a broad range of medical literature.[28–32]

Unlike prior studies focused on pre-pandemic trends, we found several trends that coincided with the COVID-19 pandemic, namely, increased hospital LOS, greater in-hospital mortality, greater use of laboratory testing, and greater costs of hospital care. The observed trends are consistent with the reported outcomes of COVID-19 patients in the literature, in particular high mortality and LOS[33,34] and cost-of-care[35], but also point to a potentially broader impact of the pandemic on the outcomes of non-COVID patients, e.g., by impacting human health resources.

Limitations

Our study has several limitations. First, although the 21 hospitals included in our study care for approximately 40% of Ontario's GIM inpatients and likely capture trends across many urban and suburban populations, findings may not generalize to smaller community hospitals. Second, we lacked individual-level data on social determinants of health or other factors that can drive patient complexity, such as availability of caregiver support or housing. Third, we captured readmission to hospitals within GEMINI and thus likely undercounted readmissions. Importantly, this should not bias comparisons across time, as the same sites were included across the study period. Further, previous studies have shown that in Ontario, 80% of readmissions occur to the same hospital[36]. Fourth, we did not have measures of appropriateness of testing or treatment and therefore could not determine whether increases in resource-based measures reflected greater clinical need, changing case mix, evolving standards of care, or changes in practice patterns. Finally, we did not have data on hospital staffing. Hence, we could not determine the extent to which the observed trends translated into operational strain on hospitals or staff, as this would also depend on how system capacity changed over time.

Conclusions

Between 2015 and 2022, there was an increase in imaging and medication ordering among GIM hospital patients, but no consistent trends in other measures of patient complexity, including patient characteristics or clinical outcomes. This suggests that the general demographic-driven increase in patient complexity that was observed in the earlier part of the 2000s may be plateauing and highlights the importance of future research into the appropriateness of imaging and medication ordering.

Author Contribution declaration

- Alireza Ghahtarani: *Formal analysis; Investigation; Visualization; Writing—original draft; Writing—review & editing*.
- Suran Roberts: *Methodology; Writing—review & editing*.
- Walter Wodchis: *Validation; Writing—review & editing*.
- Fahad Razak: *Validation; Writing—review & editing*.
- Amol Verma: *Conceptualization; Validation; Supervision; Funding acquisition; Writing—original draft; Writing—review & editing*.
- Vahid Sarhangian: *Conceptualization; Methodology; Supervision; Funding acquisition; Writing—original draft; Writing—review & editing*.

Human Ethics and Consent to Participate declarations

Our study received ethics approval from the University of Toronto and from all participating hospitals through Clinical Trials Ontario with Unity Health Ontario as the Research Ethics Board (REB) of Record. Informed consent from patients was waived, as this was a low-risk retrospective study using de-identified, anonymized data presented in aggregate form.

Clinical trial number

Not applicable.

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Figure legends

Figure 1. Estimated rate ratios (relative to 2015-2016) for complex and non-complex categories for complexity measures related to Patient Characteristics.

Figure 2. Estimated rate ratios (relative to 2015-2016) for complex and non-complex categories for complexity measures related to Outcomes.

Figure 3. Estimated rate ratios (relative to 2015-2016) for complex and non-complex categories for complexity measures related to Resource Use.

Tables

Table 1. Definition of complexity for each measure considered

Variable	Definition	Type
Charlson Comorbidity Index (CCI)	>=5 is complex	Patient characteristics
LOS	>=10 days is complex	Outcomes
Diagnoses	>=5 is complex	Patient characteristics
Lab tests	>=518 is complex (90^{th} percentile)	Resource use
ICU admission	Admission to ICU (at any point during hospitalization) is complex, no admission to ICU is non-complex.	Outcomes
Readmission after 30 days	Readmission after 30 days is complex.	Outcomes
In-hospital death	Death in hospital is complex.	Outcomes
Advanced age	>=75 is complex	Patient characteristics

mLAPS	>=53 (90th percentile)	Patient characteristics
Radiology interventions	>=1 is complex	Resource use
Radiograph	>=4 is complex (90th percentile)	Resource use
Blood transfusion	>=1 is complex	Resource use
MRI	>=1 is complex	Resource use
Ultrasound	>=1 is complex	Resource use
CT-scan	>=1 is complex	Resource use
Medication orders	>=54 is complex (90th percentile)	Resource use
All Radiology Tests	>=8 (90th percentile)	Resource use
Adjusted cost	>= 20143 (90th percentile)	Resource use

Table 2. Hospitalization and patient characteristics

Year	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
No. of hospitalizations	103,851	107,599	112,639	116,487	119,744	112,407	121,103
Daily admissions, median (25th-75th)	286 (266-301)	296 (276-313)	308 (290-327)	319 (299-339)	332 (311-346)	309 (288-330)	332 (313-350)
Daily discharges, median (IQR)	314 (182-344)	327 (184-363)	341 (196-380)	354 (200-392)	373.50 (207-403)	333 (203-381)	371 (219-410)
Age, median (IQR)	73 (57-84)	73 (58-84)	73 (58-84)	72 (58-84)	72 (57-84)	72 (58-83)	72 (58-83)
Female, No. (%)	53335 (51.40)	55055 (51.20)	57353 (50.90)	58680 (50.40)	60174 (50.30)	54731 (48.70)	59786 (49.40)
Comorbidity score, No. (%)							
Charlson comorbidity index score = 0	45334 (43.65)	46533 (43.25)	48988 (43.49)	50922 (43.71)	51358 (42.89)	49189 (43.76)	52728 (43.54)
Charlson comorbidity index score = 1	18180 (17.51)	19043 (17.70)	19688 (17.48)	20795 (17.85)	21624 (18.06)	19843 (17.65)	21242 (17.54)
Charlson comorbidity index score = 2	17722 (17.06)	18433 (17.13)	19286 (17.12)	19497 (16.74)	20196 (16.87)	19010 (16.91)	20754 (17.14)
Charlson comorbidity index score >= 3	22615 (21.78)	23590 (21.92)	24677 (21.91)	25273 (21.70)	26566 (22.19)	24365 (21.68)	26379 (21.78)
IP diagnoses, median (IQR)	5 (3-8)	5 (3-8)	5 (3-8)	5 (3-8)	5 (3-7)	5 (3-8)	5 (3-8)
Frailty score, median (IQR) (patients over 65 years old)	4 (2-5)	4 (2-5)	4 (2-5)	4 (2-5)	4 (2-5)	4 (2-5)	4 (3-5)
mLAPS 24 hours, median (IQR) (16 hospitals)	24 (11-38)	24 (11-39)	23 (11-38)	23 (11-37)	21 (10-36)	22 (11-37)	22 (11-37)

NEWS, median (IQR)	2 (2-4)	2 (2-4)	2 (2-4)	2 (2-4)	2 (2-4)	2 (2-4)	2 (2-4)
Transferred from acute care institutions, No. (%)	2733 (2.63)	2640 (2.45)	2830 (2.51)	3204 (2.75)	3355 (2.80)	4045 (3.60)	4862 (4.01)