

Original Research Article

Polypharmacy and potentially inappropriate medication use in hospitalized geriatric patients: a prospective evaluation using the American geriatrics society 2023 Beers criteria

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ABSTRACT

Background: Elderly inpatients are disproportionately burdened by polypharmacy and potentially inappropriate medication (PIM) use, driven by age-related pharmacokinetic change, multimorbidity, and fragmented prescribing. Systematic Beers criteria-based prescription review is rarely practised in Indian tertiary care settings, and regional economic data on this problem are lacking.

Methods: A prospective observational study was conducted from January-June 2025 at a 1200-bed tertiary care teaching hospital in Raichur, Karnataka, enrolling 100 in-patients aged ≥ 65 years from general medicine, orthopaedics, ophthalmology, and surgery departments. Prescribed drugs were evaluated against the four categories of the American Geriatrics Society (AGS) 2023 Beers Criteria, and drug costs were used to compute the economic burden of inappropriate prescribing. Descriptive statistics, chi-square, Pearson correlation, and one-way ANOVA were applied.

Results: Female patients constituted 61% of the cohort; 57% were aged 65-70 years. Mean drugs per prescription was 11.13 ± 3.72 (range: 5-22). A total of 293 PIM occurrences were identified in 99 of 100 patients (99%); mean 2.93 ± 1.67 per patient. Proton pump inhibitors (40.3%), non-steroidal anti-inflammatory drugs (14.7%), and tramadol (12.6%) were the most prevalent inappropriate classes. Mean PIM-attributable cost was INR 1021.98 ± 1113.04 per patient (13.64% of total inpatient drug expenditure); one-way ANOVA across three cost strata showed significant differences ($F=18.87$; $p<0.001$).

Conclusions: PIM use was observed in a substantial proportion of elderly inpatients, with proton pump inhibitors, NSAIDs, and opioids frequently identified. The findings support continued individualized medication review, Beers Criteria integration, and physician-pharmacist collaboration to optimize safe, effective, and patient-centered geriatric pharmacotherapy.

Keywords: Beers criteria, Geriatric pharmacotherapy, Polypharmacy, Potentially inappropriate medications, Prescription appropriateness, Tertiary care hospital

INTRODUCTION

India is undergoing one of the most rapid demographic transitions in the world. The country's elderly population (aged 60 years and above) stood at approximately 90

million in 2020 and is projected to surpass 319 million by 2050—a demographic reality that carries profound implications for healthcare resource planning and clinical practice.^{1,2}

The majority of hospitalized geriatric patients carry multiple co-existing chronic conditions. Multimorbidity, defined as the simultaneous presence of two or more chronic diseases, is reported in 70% to 80% of elderly inpatients in tertiary care settings.^{3,4} Managing this complexity inevitably results in polypharmacy. Defined as the concurrent use of five or more medications, polypharmacy is pervasive in geriatric inpatient settings, with rates of 52% to 74% documented across Indian tertiary care hospitals.⁵⁻⁷

Aging induces a series of pharmacokinetic and pharmacodynamic changes that fundamentally alter how drugs behave in the body. Reductions in glomerular filtration rate and hepatic enzyme activity prolong drug half-lives; decreased plasma albumin reduces protein binding, increasing the fraction of free (active) drug; and reduced lean body mass alters the volume of distribution. Together, these changes heighten susceptibility to dose-dependent toxicity and drug-drug interactions with each additional medication added to the regimen.^{8,9}

Inappropriate prescribing—where the clinical risks of a medication outweigh its potential benefits in the context of an older patient's overall health—is a modifiable and significant cause of preventable adverse drug events, hospitalizations, functional decline, and increased healthcare expenditure.^{9,10} The AGS 2023 Beers criteria is the most extensively validated and widely adopted explicit tool for identifying PIMs in elderly patients. The 2023 update classifies medications across four categories: those unconditionally inappropriate in older adults (Category 1); those inappropriate due to drug-disease or drug-syndrome interactions (Category 2); those requiring cautious use in view of a defined risk (Category 3); and those necessitating dose modification or avoidance based on estimated glomerular filtration rate (Category 4).¹¹

Despite their demonstrated utility, Beers Criteria-based prescribing reviews are rarely embedded in routine clinical practice at Indian tertiary care hospitals. Published studies from South India document PIM prevalence rates of 11.6% to 61.9%, reflecting considerable variability driven by study setting, patient mix, and the version of the criteria applied.¹²⁻¹⁴ Regional data specifically addressing PIM burden and its direct economic implications among geriatric inpatients in North Karnataka are limited. Therefore, the present study aimed to prospectively evaluate polypharmacy patterns and PIM prevalence among hospitalized elderly patients at NMCH and RC, Raichur, using the AGS 2023 Beers criteria, and to quantify direct medication cost attributable to inappropriate prescribing in this population.

The objectives of this study were to assess the extent of polypharmacy among hospitalized patients aged ≥ 65 years; determine the frequency of PIM use according to the AGS 2023 Beers criteria; identify the most commonly prescribed PIMs and classify them across the four Beers criteria categories; and estimate the direct medication cost

attributable to PIMs and its proportion of the total inpatient drug expenditure.

METHODS

Study design and setting

A prospective, observational, hospital-based study was conducted from 1 January 2025 to 30 June 2025 at Navodaya Medical College Hospital and Research Centre (NMCH and RC), Raichur—a 1200-bed multi-specialty tertiary care teaching hospital. Patients admitted to the general medicine, orthopaedics, ophthalmology, and surgery departments were considered for enrolment. Institutional Ethics Committee approval was obtained prior to data collection, and the study was conducted in conformity with the principles of the Declaration of Helsinki (2013 revision). This study is reported in accordance with the STROBE (Strengthening the reporting of observational studies in epidemiology) checklist for observational studies.

Inclusion and exclusion criteria

Patients of either sex aged 65 years and above, admitted as in-patients for more than 24 hours, and who provided written informed consent were included. Patients below 65 years of age, those with incomplete prescription or medical records, day-care or day-surgery admissions, and terminally ill patients were excluded.

Sample size and data collection

Based on previously published Indian studies reporting PIM prevalence of approximately 60%, a minimum sample size of 93 patients was estimated to detect prevalence with a 10% margin of error at a 95% confidence level. A convenience sample of 100 patients fulfilling the eligibility criteria was consecutively enrolled during the study period. A structured, pre-validated data collection form captured patient demographics, admitting department, length of hospital stay, pre-existing co-morbidities, all prescribed medications (generic name, trade name, dose, route, frequency, duration), relevant investigations, and primary diagnosis. Drug acquisition costs were obtained from institutional pharmacy purchase records and standard retail price lists; unit costs were used to compute total direct medication cost per admission.

Identification and classification of PIMs

All medications prescribed to each patient were systematically evaluated against the AGS 2023 Beers criteria across all four categories. Trade name and spelling variants encountered in handwritten prescriptions were reconciled to standard International Nonproprietary Names before analysis. A drug was classified as a PIM if it appeared in any Beers criteria category, irrespective of dose or duration. Duration-based recommendations were

applied when treatment duration data were available; when unavailable, medications were conservatively classified per the Beers list to avoid underestimating PIM exposure. A drug appearing in more than one category was counted once per relevant category but recorded as a single PIM occurrence for frequency analysis. For category 4 (renal-adjustment) drugs, classification was based on presence in the criteria list; estimated glomerular filtration rate was not consistently available for all patients, so these drugs were flagged as PIMs with acknowledgement of this limitation.

Economic analysis

The direct cost attributable to each PIM per patient was computed by multiplying unit drug acquisition price by dose, frequency, and duration of administration. The sum of these costs per patient constituted the PIM-related cost, expressed in Indian Rupees (INR) and as a proportion of total inpatient medication cost (PIM cost contribution, %). Patients were stratified into low (0.01%-15.00%), moderate (>15.00%-30.00%), and high (>30.00%) PIM cost-contribution groups; patients with 0% contribution were categorized separately. Complete cost data were available for 94 patients, and economic analysis was performed on this subset.

Statistical analysis

Data were entered in Microsoft excel 2019 and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Descriptive statistics (frequencies, proportions, mean, standard deviation, range) computed for all variables. Chi-square tests assessed the distribution of categorical polypharmacy variables. Pearson's correlation coefficient examined associations between continuous economic parameters. One-way analysis of variance (ANOVA) with post-hoc Tukey's HSD test compared PIM-related costs across the three contribution strata. All tests were two-tailed; $p < 0.05$ was considered statistically significant.

RESULTS

Demographic characteristics

The demographic profile of 100 enrolled patients is summarized in Table 1. Most patients (57%) belonged to 65-70-year age category, with declining representation across older strata. Female patients constituted 61% of the cohort, outnumbering males (39%) by approximately 1.6:1. Admissions of 5-9 days were most common (49%), followed by 1-4 (45%) and 10-14 days (6%). Seventy-one percent of patients carried at least 1 chronic condition at admission; a single co-morbidity was most frequent (38%), followed by 2 (23%), 3 (8%), and 4 (2%).

Polypharmacy

The polypharmacy profile is presented in Table 2. Mean drugs prescribed per patient was 11.13 ± 3.72 (median: 11;

range: 5-22). The 6-10 drug category was most prevalent (49%), followed by 11-15 (38%), 16-20 (10%), >20 (2%), and 1-5 (1%). The distribution was significantly skewed toward higher drug counts ($\chi^2=97.50$; $df=4$; $p<0.001$). Overall, 99% of prescriptions contained six or more concurrent medications.

PIMs identified

A total of 293 PIM occurrences were identified across the 100 prescriptions; 99 of 100 patients (99%) received at least one PIM. Mean PIMs per patient was 2.93 ± 1.67 (median: 3; range: 0-8), with a mean PIM exposure duration of 3.62 ± 2.20 days (median: 3.00; range: 1-10 days). Drug-wise frequency is in Table 3, drug-class breakdown in Table 4, and classification across the four AGS 2023 Beers categories in Table 5.

Proton pump inhibitors were the most frequently encountered PIM class, accounting for 118 of 293 occurrences (40.3%), with pantoprazole alone representing 116 instances (39.6%). This was followed by non-steroidal anti-inflammatory drugs-diclofenac sodium, aceclofenac, and ibuprofen combined-with 43 occurrences (14.7%); tramadol (37 occurrences; 12.6%); benzodiazepines (alprazolam and lorazepam combined; 26 occurrences; 8.9%); aminoglycosides (amikacin; 15 occurrences; 5.1%); antidiabetic agents (metformin, sliding scale insulin; 18 occurrences; 6.1%); and metoclopramide (12 occurrences; 4.1%). Together, proton pump inhibitors, NSAIDs, tramadol, and benzodiazepines accounted for 224 of 293 occurrences (76.5%) of all identified PIMs.

Economic impact of PIMs

The economic analysis, based on 94 patients with complete cost data, is summarized in Table 6. Mean total inpatient medication cost per patient was INR 9819.36 ± 8039.68 (median: INR 6563.00; range: INR 1128.00-35832.55). Mean PIM-attributable cost was INR 1021.98 ± 1113.04 per patient (median: INR 633.00; range: INR 0.00-6765.30), representing a mean of $13.64 \pm 11.76\%$ of total inpatient drug expenditure (median: 9.86%; range: 0.00%-54.92%). A statistically significant, moderate positive correlation was found between total medication cost and PIM cost (Pearson $r=0.429$; $p<0.001$); a stronger correlation was observed between PIM cost and its percentage contribution to total cost ($r=0.555$; $p<0.001$).

One-way ANOVA across 3 PIM cost-contribution strata-low ($n=60$), moderate ($n=23$), and high ($n=10$)-revealed highly significant between-group differences for PIM cost ($F=18.87$; $df(2, 90)$; $p<0.001$) and total medication cost ($F=9.89$; $df(2, 90)$; $p<0.001$). Mean PIM cost in high-contribution stratum (INR 2777.24 ± 1785.43) was approximately 3.4 $\times$ that in low-contribution stratum (INR 828.26 ± 797.91). Distribution of PIM cost contributions across individual patients is illustrated in Figure 1.

Table 1: Demographic profile of geriatric patients admitted during the study period, (n=100).

Parameters	N	Percentage (%)
Age group (in years)		
65-70	57	57.0
71-75	22	22.0
76-80	13	13.0
81-85	5	5.0
86-90	2	2.0
91 and above	1	1.0
Sub-total	100	100.0
Gender		
Male	39	39.0
Female	61	61.0
Sub-total	100	100.0
Length of hospital stay (days)		
1-4	45	45.0
5-9	49	49.0
10-14	6	6.0
Sub-total	100	100.0
Pre-existing co-morbidities (number)		
None	29	29.0
One	38	38.0
Two	23	23.0
Three	8	8.0
Four	2	2.0
Sub-total	100	100.0

*Percentages are rounded to one decimal place. Sub-total rows represent column totals for each demographic parameter.

Table 2: Distribution of patients by number of drugs per prescription-polypharmacy analysis, (n=100).

Number of drugs per prescription	N	Percentage (%)
1-5 drugs	1	1.0
6-10 drugs	49	49.0
11-15 drugs	38	38.0
16-20 drugs	10	10.0
More than 20 drugs	2	2.0
Total	100	100.0

* $\chi^2=97.50$; $df=4$; $p<0.001$ *. Mean no. of drugs per prescription= 11.13 ± 3.72 (range: 5-22), 99% of prescriptions contained 6 or more drugs χ^2 =Chi-square goodness-of-fit statistic; df =degrees of freedom; * $p<0.05$ is considered statistically significant. Polypharmacy is defined as the concurrent use of five or more medications. Ninety-nine percent of prescriptions contained six or more drugs.

Table 3: Frequency, percentage, and cumulative percentage of PIMs identified according to the AGS 2023 Beers criteria (total occurrences=293; n=100 prescriptions).

Drug (generic name)	N	Percent	Cum.	Beers category
Pantoprazole and other PPI	116	39.6%	39.6%	Cat. 1, 2, 3
Diclofenac sodium and aceclofenac (NSAIDs)	38	13.0%	52.6%	Cat. 1, 2, 4
Tramadol (opioid analgesic)	37	12.6%	65.2%	Cat. 2, 3, 4
Alprazolam (benzodiazepine)	24	8.2%	73.4%	Cat. 1, 2
Amikacin (aminoglycoside)	15	5.1%	78.5%	Cat. 4
Metoclopramide (prokinetic agent)	12	4.1%	82.6%	Cat. 1, 2
Metformin (antidiabetic)	10	3.4%	86.0%	Cat. 2, 3, 4
Insulin, sliding scale (antidiabetic)	8	2.7%	88.7%	Cat. 1
Ibuprofen (NSAID)	5	1.7%	90.4%	Cat. 1, 2, 4
Ciprofloxacin (fluoroquinolone)	5	1.7%	92.1%	Cat. 2, 4
Furosemide (loop diuretic)	4	1.4%	93.5%	Cat. 2, 3, 4
Aspirin for primary prevention	3	1.0%	94.5%	Cat. 1, 2
Esomeprazole (PPI)	2	0.7%	95.2%	Cat. 1, 2, 3

Continued.

Drug (generic name)	N	Percent	Cum.	Beers category
Lorazepam (benzodiazepine)	2	0.7%	95.9%	Cat. 1, 2
Chlorzoxazone (muscle relaxant)	2	0.7%	96.6%	Cat. 1
Ketoconazole, oral (antifungal)	2	0.7%	97.3%	Cat. 1
Spironolactone (above 25 mg per day)	2	0.7%	98.0%	Cat. 2, 4
Triamcinolone (systemic corticosteroid)	2	0.7%	98.7%	Cat. 2, 3
Hydrochlorothiazide (thiazide diuretic)	1	0.3%	99.0%	Cat. 2, 3, 4
Nortriptyline (TCA)	1	0.3%	99.3%	Cat. 1, 2
Gabapentin (antiepileptic)	1	0.3%	99.6%	Cat. 2, 4
Amitriptyline (TCA)	1	0.3%	100.0%	Cat. 1, 2, 3
Total	293	100.0	-	-

*Cat.=Beers Criteria category; n=frequency of occurrence (number of prescriptions containing the drug); (%)=percentage of total PIM occurrences (N=293); Cum.(%)=cumulative percentage in descending frequency order. Mean number of PIMs per patient=2.93±1.67 (range: 0-8; median: 3). Ninety-nine of 100 patients received at least one PIM. TCA=Tricyclic antidepressant; NSAID=Non-steroidal anti-inflammatory drug; PPI=Proton pump inhibitor. Trade name and spelling variants were standardized to generic names before analysis.

Table 4: Drug class-wise distribution of PIMs identified according to the AGS 2023 Beers criteria (total occurrences=293).

Drug class	Drugs identified	No. of drugs	N	Percentage
Proton pump inhibitors	Pantoprazole, esomeprazole	2	118	40.3%
Non-steroidal anti-inflammatory drugs	Diclofenac sodium, aceclofenac, ibuprofen	3	43	14.7%
Opioid analgesics	Tramadol	1	37	12.6%
Benzodiazepines	Alprazolam, lorazepam	2	26	8.9%
Aminoglycosides	Amikacin	1	15	5.1%
Prokinetic agents	Metoclopramide	1	12	4.1%
Antidiabetic agents	Metformin, insulin (sliding scale)	2	18	6.1%
Antihypertensives and diuretics	Furosemide, spironolactone, hydrochlorothiazide	3	7	2.4%
Fluoroquinolone antibiotics	Ciprofloxacin	1	5	1.7%
Anticholinergics and tricyclic antidepressants	Amitriptyline, nortriptyline	2	2	0.7%
Antiplatelet agents	Aspirin	1	3	1.0%
Systemic corticosteroids	Triamcinolone	1	2	0.7%
Others^a	Gabapentin, ketoconazole, chlorzoxazone	3	5	1.7%
Total	-	23	293	100.0

^a- Others: gabapentin (antiepileptics), ketoconazole (antifungals), and chlorzoxazone (muscle relaxants). Total unique PIM drugs identified=23 (including variant trade-name preparations standardized to generic names). Percentages are based on total PIM occurrences (n=293).

Table 5: Category-wise classification of identified PIMs according to the AGS 2023 Beers criteria.

Cat.	Category description (AGS 2023)	Drugs encountered in this study	No. of drugs	Clinical implication
1	PIMs in older adults (unconditional)	Alprazolam, amitriptyline, aspirin (primary prevention), chlorzoxazone, diclofenac, aceclofenac, esomeprazole, ibuprofen, insulin (sliding scale), ketoconazole, lorazepam, metoclopramide, nortriptyline, pantoprazole	14	Avoid in all older adults regardless of clinical context
2	PIMs due to drug-disease or drug-syndrome interactions	Aceclofenac, alprazolam, amitriptyline, aspirin, ciprofloxacin, diclofenac, esomeprazole, furosemide, gabapentin, hydrochlorothiazide, ibuprofen, lorazepam, metformin, metoclopramide, nortriptyline, pantoprazole, spironolactone, tramadol, triamcinolone	19	May exacerbate underlying condition; must document active co-morbidities

Continued.

Cat.	Category description (AGS 2023)	Drugs encountered in this study	No. of drugs	Clinical implication
3	PIMs to be used with caution	Amitriptyline, esomeprazole, furosemide, hydrochlorothiazide, metformin, pantoprazole, tramadol, triamcinolone	8	Use only when benefit outweighs risk; requires close monitoring
4	Medications requiring dose adjustment or avoidance based on kidney function	Aceclofenac, amikacin, ciprofloxacin, diclofenac, furosemide, gabapentin, hydrochlorothiazide, ibuprofen, metformin, spironolactone, tramadol	11	Dose-reduce or avoid; eGFR must be documented at prescribing

*Total unique PIMs=23. Several drugs appear in more than one category, reflecting multifaceted risk mechanisms. Total occurrences=293. AGS=American Geriatrics Society; eGFR=Estimated glomerular filtration rate; Cat=Category. Several drugs appear in more than one category, reflecting multifaceted risk profiles in older adults. Total unique PIMs identified across all categories=23. Total PIM occurrences across 100 prescriptions=293.

Table 6: Summary statistics of medication costs and economic impact of PIMs in geriatric patients with complete cost data, (n=94).

Parameters	Mean±SD	Median	Minimum	Maximum	P value
Total medication cost (INR)	9819.36±8039.68	6563.00	1128.00	35832.55	-
PIM cost (INR)	1021.98±1113.04	633.00	0.00	6765.30	-
PIM cost contribution (%)	13.64±11.76	9.86	0.00	54.92	-
Number of PIMs per patient	2.93±1.67	3	0	8	-
Duration of PIM exposure (days)	3.62±2.20	3.00	1.00	10.00	-
Pearson r: total medication cost vs. PIM cost	R=0.429	-	-	-	<0.001*
Pearson r: PIM cost vs. cost contribution (%)	R=0.555	-	-	-	<0.001*
One-way analysis of variance: PIM cost across strata	F=18.87; df (2, 90)	-	-	-	<0.001*
One-way analysis of variance: total medication cost across strata	F=9.89; df (2, 90)	-	-	-	<0.001*

*INR=Indian Rupees; SD=Standard deviation; r=Pearson correlation coefficient; F=F-statistic (one-way analysis of variance); df = degrees of freedom. *p<0.05 is considered statistically significant (two-tailed). PIM cost contribution (%)=(PIM-related cost ÷ total inpatient medication cost) × 100. Stratification: Low=0.01-15.00% (n=60); Moderate=>15.00-30.00% (n=23); High=>30.00% (n=10); No PIM=0.00% (n=1). Patient-level distribution of cost contribution is illustrated in Figure 1.

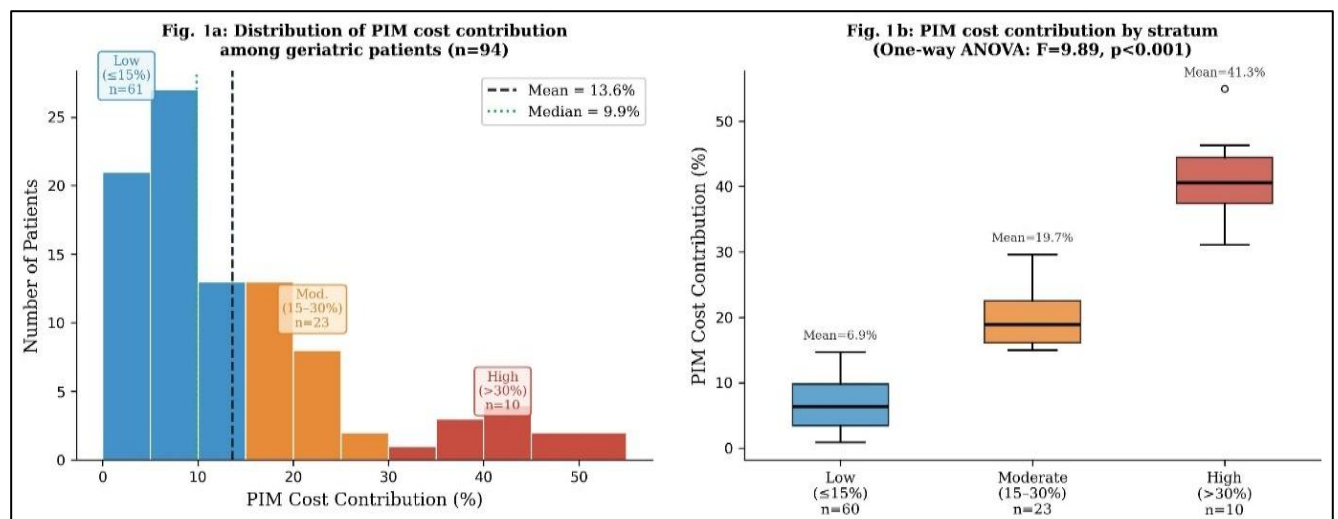


Figure 1: Distribution of PIM cost contribution (%) among geriatric inpatients (n=94 patients with complete cost data available).

*Left panel: histogram of cost contribution (%), showing frequency of patients at each level; the dashed vertical line indicates the mean (13.64%) and the dotted line the median (9.86%). Bars are colour-coded by stratum: low contribution (0.01%-15%), orange for moderate (15%-30%), and red for high (above 30%). Right panel: side-by-side box plots comparing PIM cost contribution (%) across the three contribution strata. Mean values (%) are annotated above each box plot. INR=Indian Rupees; SD=Standard deviation.

DISCUSSION

This prospective study evaluated polypharmacy patterns and prescription appropriateness among 100 geriatric inpatients at a tertiary care teaching hospital in North Karnataka using the AGS 2023 Beers Criteria. The findings reveal a substantial burden of potentially inappropriate prescribing and extreme polypharmacy, consistent with data from comparable hospital settings across India and internationally, with significant economic consequences at the individual patient level.

Demographic profile

The predominance of patients in the 65-to-70-year age group (57%) reflects the typical distribution seen in Indian tertiary care geriatric studies, where younger elderly individuals more often present to institutional facilities while older, frailer patients are managed at home or in smaller facilities.^{15,16} The female majority (61%) is consistent with established patterns of greater healthcare utilization and longer life expectancy among older women.¹⁷ The high prevalence of at least one pre-existing chronic condition in 71% of patients (with 33% carrying two or more) directly underpins the extreme polypharmacy and high PIM exposure observed in this cohort.⁴

Polypharmacy

A mean of 11.13 drugs per prescription markedly exceeds the conventional five-drug polypharmacy threshold. This is consistent with the 10.85 drugs per prescription reported by Wazir and colleagues⁷ in a similar design at a Hyderabad tertiary care centre, and with international data documenting polypharmacy rates of 60% to 70% among hospitalized elderly patients.^{18,19} The mechanisms underlying extreme polypharmacy are well characterized: fragmented prescribing by multiple disease-specialist physicians without a coordinating review; carry-forward of medications from previous admissions; disease-specific guidelines that address individual conditions in isolation; and an institutional culture that equates adding medications with comprehensive care.^{20,21}

PIMs-prevalence and patterns

A PIM prevalence of 99% places this study among the highest reported in the global literature. The near-identical figure of 99.3% documented by Regina and colleagues at a Brazilian tertiary care centre using the 2019 Beers Criteria suggests that hospitalized geriatric populations with high polypharmacy and multimorbidity burden approach universal exposure to inappropriate prescribing regardless of geography.²² Indian studies using earlier Beers Criteria versions report prevalence ranging from 11.6% (Motalebzadeh and colleagues) to 64.6% (Ruqiya and colleagues) and 60.1% (Rishabh and colleagues).²³⁻²⁵ The higher figure in the present study likely reflects application of the more inclusive 2023

criteria across four departments including orthopaedics and surgery, where opioid analgesics and aminoglycosides are commonly prescribed.

Proton pump inhibitors (40.3%), led by pantoprazole (39.6%), constituted the dominant PIM class. These are among the most frequently initiated drugs in hospital settings, often started empirically for stress ulcer prophylaxis without formal indication and continued indefinitely without reassessment.²⁶ Long-term proton pump inhibitor use in elderly patients carries well-documented risks including *Clostridioides difficile* infection, osteoporotic fractures, hypomagnesaemia, and vitamin B12 deficiency-all amplified in the vulnerable geriatric host.¹¹

NSAIDs (14.7%) and tramadol (12.6%) together constituted more than a quarter of all PIM occurrences, reflecting widespread use for acute musculoskeletal pain in orthopaedic and surgical admissions. NSAID use in older adults is associated with a fourfold increase in gastrointestinal bleeding risk, dose-dependent acute kidney injury, fluid retention, and exacerbation of heart failure.^{13,14} Tramadol is classified across three Beers Criteria categories (2, 3, and 4), reflecting risks of falls, seizures, severe hyponatraemia, and dose accumulation in renal impairment.¹¹ Benzodiazepines-alprazolam and lorazepam-constituted 8.9% of PIM occurrences, consistent with earlier reports from Indian inpatient cohorts.^{13,24} The case against benzodiazepines in older adults is unambiguous: prolonged use is associated with a 50% increase in the risk of hip fracture, accelerated cognitive decline, and a significantly increased risk of developing Alzheimer's dementia.^{27,28} Despite this evidence, these agents continue to be prescribed for anxiety, insomnia, or alcohol withdrawal without adequate consideration of non-pharmacological alternatives.

Amikacin (5.1%) and metoclopramide (4.1%) together accounted for approximately 9% of occurrences. The AGS 2023 Beers Criteria flag aminoglycosides under Category 4, mandating dose individualization based on estimated glomerular filtration rate-a step frequently omitted in busy inpatient surgical settings.¹¹ Metoclopramide is flagged across two categories due to its cumulative risk of tardive dyskinesia and other extrapyramidal effects, disproportionately prevalent and often irreversible in elderly patients even at standard doses.²⁹

Economic burden

The mean PIM-related cost of INR 1021.98 per patient-13.64% of total inpatient drug expenditure-represents a quantifiable, potentially avoidable financial burden. Individual patients experienced contributions as high as 54.92%, underscoring the heterogeneity of this burden. ANOVA showed that patients in the high-contribution stratum (>30%; n=10) bore a mean PIM cost of INR

2777.24-approximately 3.4 times the mean in the low-contribution stratum (INR 828.26; n=60). These data align with published evidence confirming that PIM use disproportionately inflates inpatient drug expenditure and is independently associated with increased emergency department visits, hospitalizations, and mortality in elderly populations.^{30,31} In the Indian context, where most elderly patients fund healthcare through direct out-of-pocket expenditure with limited insurance coverage, this avoidable cost threatens household financial resilience and may lead to rationing of essential medications.

Clinical and policy implications

Several actionable responses follow. First, the near-universal PIM prevalence and extreme polypharmacy support formal integration of clinical pharmacists into geriatric ward rounds, admission medication reconciliation, and discharge planning; pharmacist-led review and deprescribing interventions reduce PIM frequency by 20% to 30% without adversely affecting patient-reported outcomes.³² Second, since pantoprazole, diclofenac/aceclofenac, and tramadol-the three most frequently identified PIMs-together account for a substantial share of identified PIMs (65.2%), institution-specific policies mandating indication documentation, defined maximum durations, and mandatory discharge reassessment for these three classes would address the largest share of inappropriate prescribing. Third, integrating AGS Beers Criteria-based clinical decision support into hospital information systems and CPOE platforms would provide real-time guidance without adding clinician workload. Fourth, structured educational modules on geriatric pharmacotherapy for postgraduate trainees and junior faculty would address the root cause through improved prescriber knowledge.

Due to the relatively small sample size, multivariable regression to identify independent predictors of PIM use was not performed. The single-centre design with a convenience sample of 100 patients restricts generalizability. The absence of clinical outcomes data-bedside-documented adverse drug events, readmission rates, length-of-stay attributable to drug-related harm, or functional decline scores-precludes causal attribution between PIM exposure and clinical outcomes. Renal function (eGFR) data were not systematically available for all patients, which may have led to underdetection of Category 4 PIMs. Non-prescription analgesics, ayurvedic preparations, and nutritional supplements were not included in the PIM analysis, potentially underestimating the true burden. A multicentre, prospective study with a larger sample, standardized renal function documentation, and systematic adverse drug event monitoring would provide more robust and generalizable estimates.

CONCLUSION

This prospective study highlights a substantial burden of polypharmacy among geriatric inpatients, with a mean of

11.13 drugs prescribed per patient, and identifies a high prevalence of PIM use (99%; 293 occurrences among 100 patients). Proton pump inhibitors, NSAIDs, tramadol, and benzodiazepines constituted the major contributors to inappropriate prescribing. PIMs accounted for a mean of 13.64% of individual inpatient drug expenditure, with patients in the high-contribution group incurring 3.4 times higher PIM-related costs than those in the low-contribution group. Importantly, the findings underscore the central and proactive role of physicians in optimizing medication use among older adults. Through careful assessment of therapeutic necessity, regular medication review, individualized prescribing, and appropriate deprescribing, physicians can substantially reduce PIM use while maintaining effective patient care. The study supports strengthening physician-led, multidisciplinary medication review, complemented by clinical pharmacist collaboration and the systematic application of Beers Criteria, to promote rational, safe, and cost-effective pharmacotherapy for geriatric inpatients in India.

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