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ORIGINAL RESEARCH ARTICLE

Prevalence and Variability in Medications Contributing to Polypharmacy in Long-Term Care Facilities

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Abstract

Background Research into which medications contribute to polypharmacy and the variability in these medications across long-term care facilities (LTCFs) has been minimal.

Objective Our objective was to investigate which medications were more prevalent among residents with polypharmacy and to determine the variability in prescribing of these medications across LTCFs.

Methods This was a cross-sectional study of 27 LTCFs in regional and rural Victoria, Australia. An audit of the medication charts and medical records of 754 residents was performed in May 2015. Polypharmacy was defined as nine or more regular medications. Logistic regression was performed to determine the association between medications and resident characteristics with polypharmacy. Analyses were adjusted for age, sex and Charlson's comorbidity index. Variability in the use of the ten most prevalent medication classes was explored using funnel plots. Characteristics of LTCFs with low ($< 30\%$), moderate (30–49%) and high ($\geq 50\%$) polypharmacy prevalence were compared.

Results Polypharmacy was observed in 272 (36%) residents. In adjusted analyses, each of the top ten most prevalent medication classes, with the exception of antipsychotics, were associated with polypharmacy. Between 7 and 23% of LTCFs fell outside the 95% control limits for each of the ten most prevalent medications. LTCFs with $\geq 50\%$ polypharmacy prevalence were predominately smaller.

Conclusion Polypharmacy was associated with nine of the ten most prevalent medication classes. There was greater than fourfold variability in nine of the ten most prevalent medications across LTCFs. Further studies are needed to investigate the clinical appropriateness of the variability in polypharmacy.

Key Points

Considerable facility-level variability in the prevalence of polypharmacy and the use of the top ten medication classes was identified.

Up to one-quarter of long-term care facilities (LTCFs) fell outside the 95% control limits of the mean for the most prevalent medication classes.

Further research is needed to determine the contribution of prescriber- and facility-related factors to the prevalence and variability of polypharmacy.

1 Introduction

Polypharmacy is highly prevalent in long-term care facilities (LTCFs) and presents considerable challenges to residents, clinicians and aged care providers [1, 2]. The use of five, nine and ten medications has been reported in up to

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91, 74 and 65% of residents of LTCFs internationally, respectively [3]. The prevalence varies considerably between facilities and geographical locations [3–5]. The harms associated with polypharmacy in LTCFs include adverse drug events (ADEs), drug–drug interactions, geriatric syndromes and hospitalizations [6, 7]. Consideration of which medications contribute to polypharmacy is important in residents of LTCFs, who are often older, frailer and more susceptible to the harms associated with polypharmacy than are those living in the community [8, 9].

In a recent systematic review on the prevalence of polypharmacy in LTCFs [3], only one of 26 studies reported the prevalence of medications separately for residents with polypharmacy [5]. This large cross-sectional Canadian study of 589 LTCFs used prescription claims data to determine the most prevalent medication classes taken by residents who received nine or more medications [5]. The most prevalent medication classes taken by residents receiving nine or more medications included diuretics (68.2%), proton-pump inhibitors (54.8%), angiotensin-converting enzyme inhibitors (51.7%) and beta-blockers (43.2%) [5].

The Australian Commission on Safety and Quality in Health Care (ACSQHC) has highlighted the importance of understanding unwarranted variation in healthcare [10, 11]. Although some variation in prescribing is justified due to differences in healthcare needs of specific populations, unwarranted variation may reflect suboptimal care [10]. Unwarranted variability may result from differences in clinician practices and access to healthcare services [10]. While variability in polypharmacy and the prevalence of specific medications is not always inappropriate, knowledge about unwarranted and unexplained variability may help target services that provide an individualized approach to improve safety and effectiveness. An individualized approach is recommended to assess the appropriateness and risk versus benefit of each medication [12]. A better understanding of variability in prescribing practices is necessary to inform initiatives to improve the quality and appropriateness of medication use in LTCFs. The ACSQHC has identified variability in prescribing of antipsychotics and opioids [10, 11]. Considerable variability in the prevalence of polypharmacy has also been reported, but few studies have investigated the variability in polypharmacy and prescribing of prevalent medication classes across LTCFs [13–16]. Prescriber- and facility-level factors, including organizational culture, bed size and staffing levels, have been associated with variability in antipsychotic use in LTCFs [13–16].

The objective of this study was to investigate which medications are more prevalent among residents with polypharmacy and the variability in the prevalence of these medications across LTCFs.

2 Methods

2.1 Study Design, Setting and Participants

A cross-sectional audit of medication charts and medical records from all residents at 27 LTCFs in regional and rural Victoria, Australia, was performed in May 2015. An LTCF, synonymous with the term ‘nursing home’ or residential aged care facility, provides supported accommodation for people requiring functional support and nursing care [17, 18]. Regional and rural areas in Victoria include regions outside the metropolitan Melbourne as defined by Regional Development Victoria [19]. Metropolitan regions include major capital cities and surrounding suburbs, regional areas include cities and towns outside of the metropolitan region, and rural areas include smaller towns in the remainder of the state. In Australian LTCFs, medication is typically prescribed by general practitioners (GPs), dispensed by community pharmacies external to the LTCFs and administered by registered nurses, enrolled nurses or care workers in accordance with local state or territory regulations [20]. All LTCFs from four health services were selected for inclusion in the study.

2.2 Data Collection

Members of the research team ($n = 4$) collected de-identified data from hardcopy or electronic medication charts and medical records of all residents in each LTCF. A standardized data collection tool was used to extract resident demographics, medical diagnoses and medication information. Demographic and clinical information included each resident’s age, sex, medical diagnoses and length of stay. Data were extracted on diagnoses included in the Charlson comorbidity index (CCI) as well as history of falls, pressure injuries and incontinence. The CCI incorporates 19 diagnoses that are weighted according to the extent to which they are predictive of mortality [21, 22]. Pilot testing of the standardized data collection tool and data extraction was performed by the research team to ensure consistency and accuracy among data collectors ($n = 4$) and data extractors ($n = 4$). This process was informed by previous aged care research conducted by the research team [23].

2.3 Medication Data

Medication data were extracted from each resident’s medication chart. The medication name and route of

administration were recorded. Polypharmacy was defined as the concurrent use of nine or more regular medications. This is the Victorian Government Department of Health and Human Services (DHHS) [24] definition and the most common definition of polypharmacy in LTCFs [3]. Using this definition, dietary supplements (including vitamin and mineral supplements, iron preparations and electrolyte solutions) and topical preparations (including lotions, creams and ointments) were excluded. Once-only, telephone orders, nurse-initiated medications, as-needed and short-term medications were also excluded. Different formulations of the same medication were counted as separate medications; however, if multiple strengths were charted, the medication was counted only once. Combination products containing more than one active ingredient were coded as a single item. Medication classes were classified according to the third level of the Anatomical Therapeutic Chemical (ATC) classification system, recommended by the World Health Organization (WHO) [25].

2.4 Statistical Analysis

The prevalence of the ten most common regular medication classes for residents with and without polypharmacy was determined. For the primary analyses, descriptive statistics were used to summarize baseline characteristics of residents with and without polypharmacy across all 27 LTCFs. Logistic regression was used to obtain unadjusted and adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the association between resident characteristics and polypharmacy. Analyses were adjusted for age, sex and CCI. For the secondary analyses, funnel plots were generated to illustrate the inter-facility variability (by number of occupied beds) in the prevalence of polypharmacy and the ten most prevalent medications classes among all residents. In the absence of a specific target rate for the prescribing of each of the most prevalent regular medication classes, control limits of 95 and 99.8% of the mean were chosen to represent the expected variation in the data. The characteristics of LTCFs were categorized into tertiles of low ($< 30\%$), moderate (30–49%) and high ($\geq 50\%$) prevalence of polypharmacy and compared using descriptive statistics. All analyses were performed using R Statistical Software (version 3.2.0) [26].

2.5 Ethical Considerations

This study was approved by the Monash University Human Research Ethics Committee (CF15/182-2015000085) and the Ballarat Health Services and St John of God Human Research Ethics Committee (LNR/15/BHSSJOG/32).

3 Results

3.1 Resident and Long-Term Care Facility (LTCF) Characteristics

Medical and medication records for 754 residents across 27 LTCFs (range 9–61 residents) were audited. The median age of residents with and without polypharmacy was 85 and 86 years, respectively. Demographic and clinical characteristics of residents by polypharmacy status are summarized in Table 1. A total of 5622 regular medications were charted for residents at a mean ± standard deviation of 7.46 ± 3.35 regular medications per resident (range 0–19). Polypharmacy (nine or more regular medications) was observed in 272 (36.0%) residents. The number of regular medications charted according to different cut-offs included 0–4 ($n = 147$ residents [19.5%]), 5–9 ($n = 407$ [56%]) and ten or more ($n = 200$ [26.5%]) regular medications. Facilities were located in regional ($n = 10$) and rural ($n = 17$) regions in Victoria, Australia, and included some facilities that provided specialist dementia and psychogeriatric care. The majority of facilities had fewer than 40 residents ($n = 20$ [74%]), and 12 (44%) had fewer than 15.

3.2 Characteristics and Medications Associated with Polypharmacy at the Resident Level

Hypertension (OR 1.51; 95% CI 1.12–2.05), depression (OR 1.96; 95% CI 1.43–2.68), ischemic heart disease (OR 2.09; 95% CI 1.49–2.94), diabetes without end-organ damage (OR 2.14; 95% CI 1.50–3.07), chronic pulmonary disease (OR 1.76; 95% CI 1.21–2.55) and a higher median CCI (OR 1.2; 95% CI 1.08–1.33) were associated with polypharmacy. Dementia was inversely associated with polypharmacy (OR 0.39; 95% CI 0.277–0.543). No association was found between osteoarthritis, incontinence, cerebrovascular disease, falls, length of stay in a LTCF and polypharmacy.

Medication classes associated with polypharmacy are presented in Table 2. The prevalence of all ten most common regular medications was higher among residents with than without polypharmacy except for antipsychotics (29% with vs. 33% without polypharmacy). In adjusted analyses, analgesics and antipyretics (OR 2.57; 95% CI 1.80–3.72), drugs for constipation (OR 2.23; 95% CI 1.63–3.08), antidepressants (OR 2.92; 95% CI 2.12–4.04), antithrombotic agents (OR 3.40; 95% CI 2.46–4.73), drugs for peptic ulcer and gastroesophageal reflux disease (GORD) (OR 4.68; 95% CI 3.35–6.60), opioids (OR 2.83; 95% CI 2.04–3.94), high-ceiling diuretics (OR 3.95; 95% CI 2.81–5.58), lipid-modifying agents – plain (OR 3.37;

Table 1 Resident characteristics by polypharmacy status

Characteristics	No polypharmacy ($n = 482$)	Polypharmacy ($n = 272$)	Unadjusted OR	95% CI
Demographics				
Age (years), median (IQR)	86 (79.0 - 90.0)	85 (78.0 - 89.0)	0.99	0.98–1.01
Male	152 (32.1)	75 (28.6)	0.85	0.61–1.18
Medical conditions				
CCI, median (IQR)	1 (1.0 - 2.0)	2 (1.0 - 3.0)	1.20	1.08–1.33
Hypertension	233 (48.9)	158 (59.2)	1.51	1.12–2.05
Osteoarthritis	149 (31.3)	96 (36.0)	1.23	0.90–1.69
Incontinence	144 (30.3)	91 (34.1)	1.19	0.87–1.64
Dementia	208 (43.7)	62 (23.2)	0.39	0.28–0.54
Depression	137 (28.8)	118 (44.2)	1.96	1.43–2.68
Falls	144 (30.3)	78 (29.2)	0.95	0.68–1.32
Ischemic heart disease	93 (19.5)	90 (33.7)	2.09	1.49–2.94
Diabetes without end-organ damage	78 (16.4)	79 (29.6)	2.14	1.50–3.07
Chronic pulmonary disease	76 (16.0)	67 (25.1)	1.76	1.21–2.55
Cerebrovascular disease	88 (18.5)	53 (20.0)	1.09	0.74–1.59
Length of stay (months), median (IQR)	17.9 (7.2 - 37.5)	19.5 (8.1 - 42.5)	1.00	1.00–1.01

Data are presented as *n* (%) unless otherwise indicated

CCI Charlson comorbidity index, *CI* confidence interval, *IQR* interquartile range, *OR* odds ratio

Table 2 The prevalence of regularly charted medications associated with polypharmacy

Medication class	No polypharmacy ($n = 482$)	Polypharmacy ($n = 272$)	OR	95% CI	Adjusted[a] OR	Adjusted[a] 95% CI
Other analgesics and antipyretics	289 (60)	213 (78.3)	2.41	1.72–3.41	2.57	1.80–3.72
Drugs for constipation	203 (42.1)	168 (61.8)	2.22	1.64–3.02	2.23	1.63–3.08
Antidepressants	184 (38.2)	173 (63.6)	2.83	2.08–3.86	2.92	2.12–4.04
Antithrombotic agents	170 (35.3)	182 (66.9)	3.71	2.72–5.1	3.40	2.46–4.73
Drugs for peptic ulcer and GORD	174 (36.1)	195 (71.7)	4.48	3.26–6.22	4.68	3.35–6.60
Opioids	122 (25.3)	136 (50)	2.95	2.16–4.05	2.83	2.04–3.94
High-ceiling diuretics	121 (25.1)	152 (55.9)	3.78	2.76–5.19	3.95	2.81–5.58
Antipsychotics	160 (33.2)	79 (29)	0.82	0.59–1.14	0.78	0.55–1.09
Lipid-modifying agents, plain	86 (17.8)	114 (41.9)	3.32	2.38–4.66	3.37	2.37–4.8
Beta-blocking agents	79 (16.4)	108 (39.7)	3.36	2.39–4.74	3.27	2.29–4.69

Data are presented as n (%) unless otherwise indicated

CI confidence interval, *GORD* gastrooesophageal reflux disease, *OR* odds ratio

[a]Adjusted for age, sex and Charlson comorbidity index

95% CI 2.37–4.80) and beta-blocking agents (OR 3.27; 95% CI 2.29–4.69) were associated with polypharmacy. No association was found between antipsychotics and polypharmacy.

3.3 Characteristics of LTCFs with Low, Medium and High Polypharmacy Prevalence

Polypharmacy prevalence varied widely across facilities, from 0 to 89% (mean 40.3%). Facility characteristics at facilities with low, medium and high prevalence of polypharmacy are presented in Table 3. Facilities with a high prevalence of polypharmacy ($n = 10$ facilities) were primarily from the one health service and had fewer than 20 occupied beds.

3.4 Variability in the Prevalence of Medications Contributing to Polypharmacy Across LTCFs

Antipsychotic prevalence varied from 0 to 95% (mean 31.6%), laxatives from 13 to 100% (mean 51.3%),

Table 3 Characteristics at facilities with a low, medium and high prevalence of polypharmacy

Characteristics[a]	Polypharmacy prevalence		
	Low (< 30%)	Medium (30–49%)	High (≥ 50%)
Facility, *n*	9	8	10
Health service[b]			
1	50.0	37.5	20.0
2	20.0	60.0	20.0
3	11.1	11.1	77.8
4	66.7	33.3	0.0
Occupied beds[b]			
≤ 20	8.4	33.3	58.3
21–30	50.0	33.3	16.7
31–40	50.0	50.0	0.0
> 40	57.1	14.3	28.6

[a]Differences in facility characteristics between levels of polypharmacy prevalence were not statistically significant (at $p < 0.05$)

[b]Reported as percentages of facilities within each health service or categories of occupied beds

antidepressants from 10 to 89% (mean 48.3%), high-ceiling diuretics from 19 to 82% (mean 40.7%), antithrombotic agents from 18 to 78% (mean 49.5%), drugs for peptic ulcer and GORD from 20 to 80% (mean 50.2), lipid-modifying agents from 0 to 57% (mean 27.6%), beta-blocking agents from 8 to 60% (mean 27.4%), opioids from 15 to 67% (mean 35.8%) and other analgesics and antipyretics from 47 to 100% (mean 70.3%).

The prevalence of polypharmacy and the top ten medication classes charted for all residents by the number of occupied beds in each facility are presented in Figs. 1 and 2. In total, 18 (67%) facilities fell within the 95 and 99.8% control limits. One facility was above the 99.8% control limit. The vast majority of facilities (74–96%) fell within the upper and lower 95% control limits of the mean for each medication class. Medication classes that exhibited the greatest variability from the mean and falling outside of the 95% control limits included drugs for constipation ($n = 7$ [26%]), antithrombotic agents ($n = 5$ [19%]), antipsychotics ($n = 4$ [15%]), antidepressants ($n = 4$ [15%]), high-ceiling diuretics ($n = 4$ [15%]) and other analgesics and antipyretics ($n = 4$ [15%]).

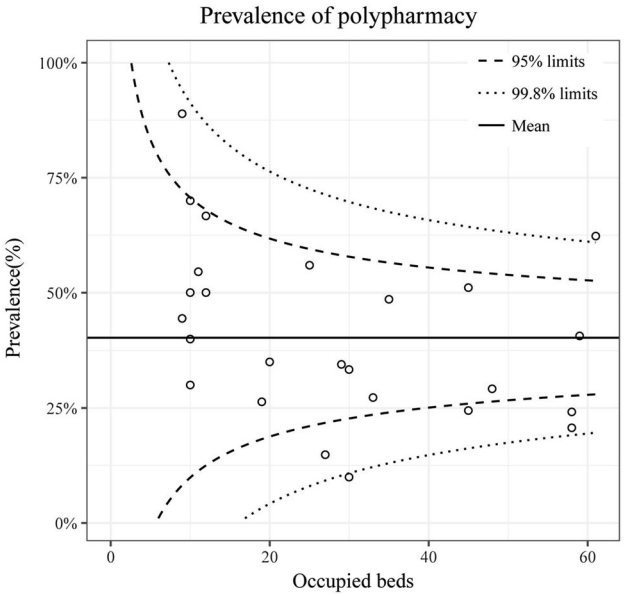

Fig. 1 Funnel plot of the inter-facility variability, by number of occupied beds, in the prevalence of polypharmacy

4 Discussion

4.1 Main Findings

Residents with polypharmacy were more likely to be prescribed at least one analgesic such as paracetamol or an opioid, a laxative, antidepressant, antithrombotic agent, drug for peptic ulcer and GORD, diuretic, lipid-modifying agent and beta-blocking agent. Antipsychotic use was not associated with polypharmacy. Between 74 and 96% of LTCFs fell within the 95% control limits of the mean for each of the most prevalent medication classes. Facilities with a high prevalence of polypharmacy were primarily from the same health service, were smaller and had a higher prevalence of each medication class, with the exception of antipsychotics.

This study found 36% of residents were charted nine or more regular medications. In comparison, our

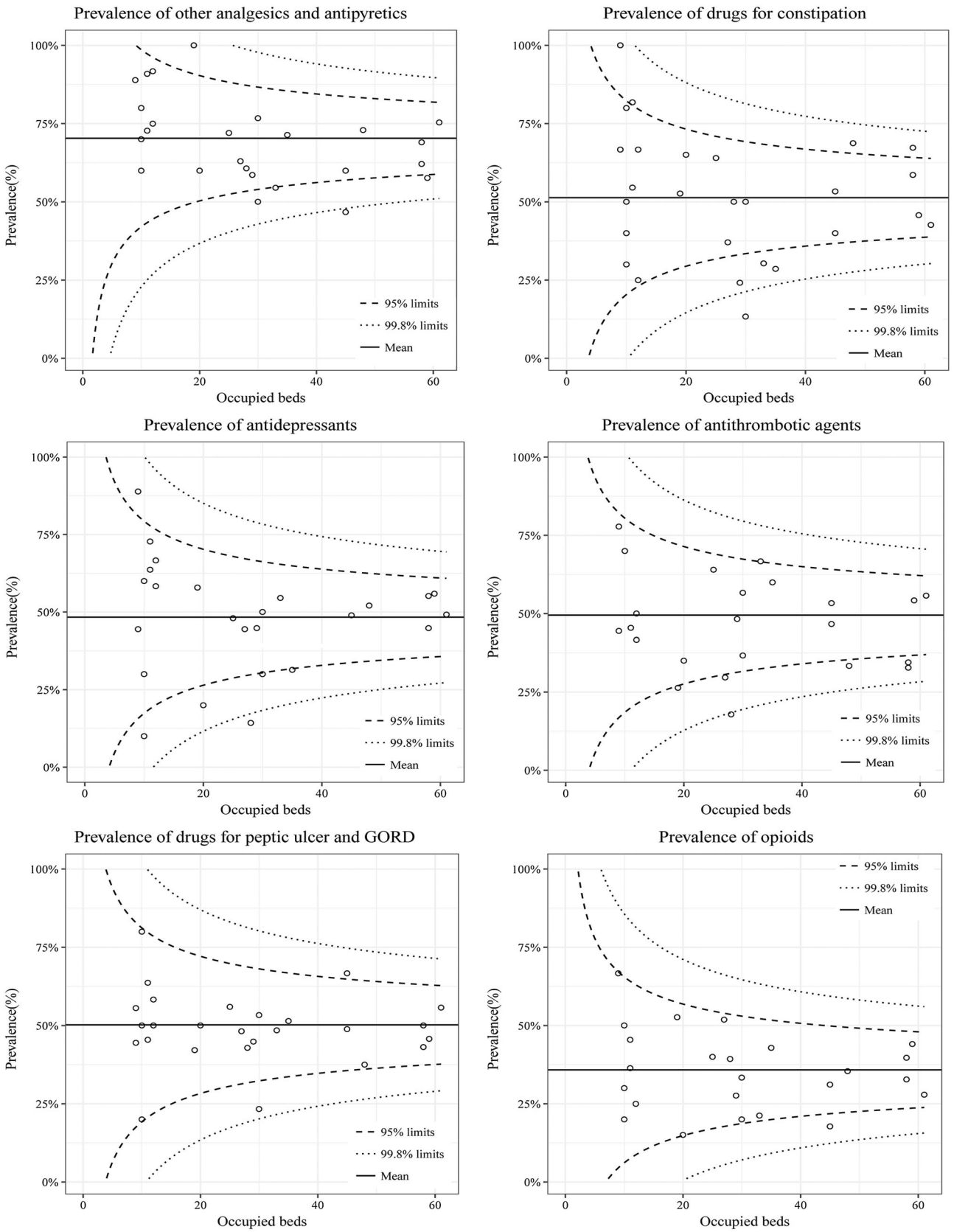

Fig. 2 Funnel plot of the inter-facility variability, by number of occupied beds, in the prevalence of the top ten most prevalent medication classes

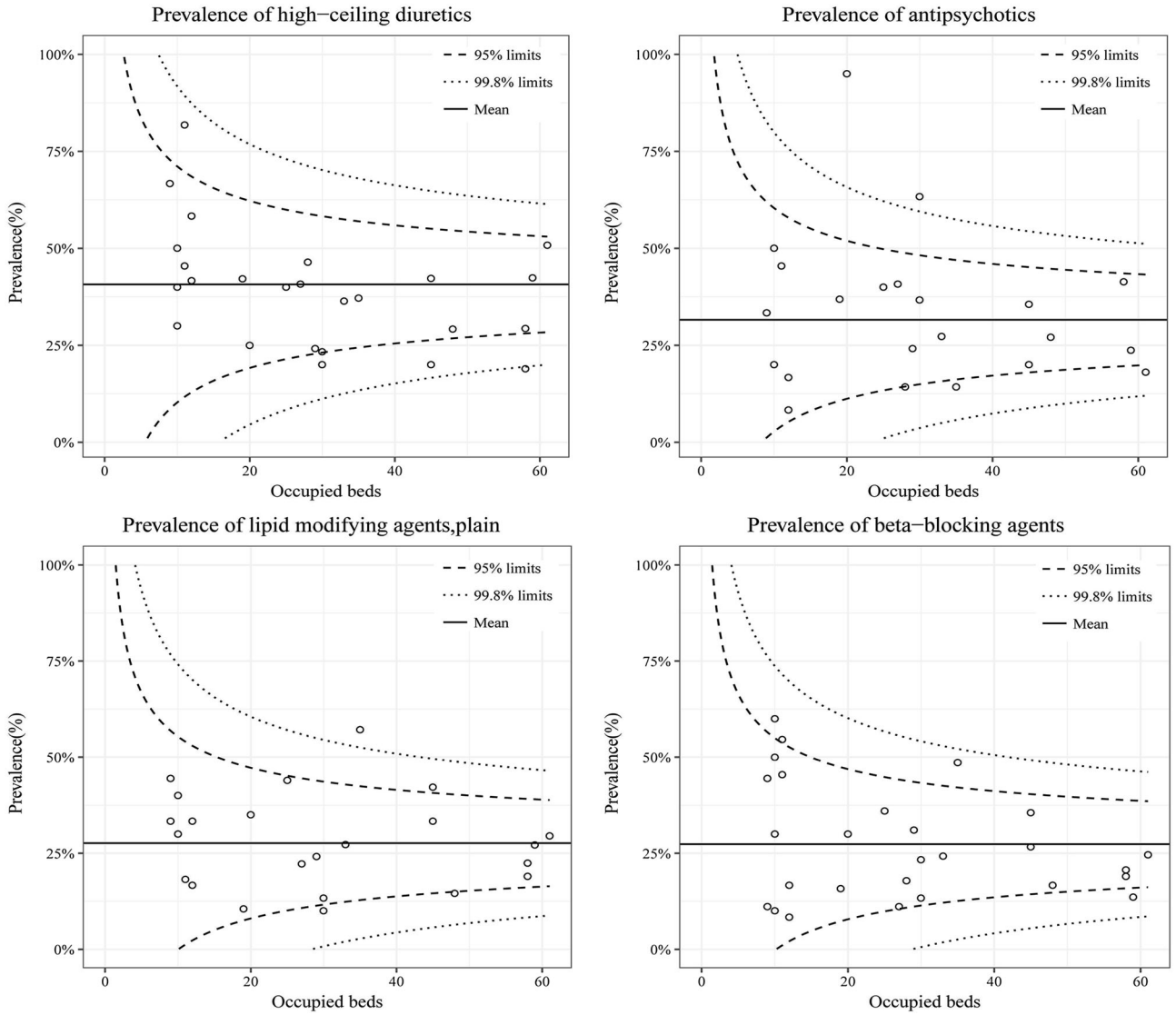

Fig. 2 continued

systematic review of the international literature found from 12.8 to 74.4% of residents in LTCFs receive nine or more medications [3]. The wide variability may reflect the inclusion or exclusion of as-needed medications, topical formulations and vitamins and herbal preparations. This poses challenges when comparing the prevalence of polypharmacy between studies [3]. Although polypharmacy is not synonymous with potentially inappropriate medication use, residents with polypharmacy are more likely to use potentially inappropriate medications [27]. Interventions targeting the reduction of unnecessary or inappropriate medication use, and subsequently polypharmacy, are likely to benefit residents in LTCFs.

4.2 Which Medications Contribute to Polypharmacy?

Diuretics, beta-blocking agents, antithrombotic agents (e.g. aspirin) and lipid-modifying agents (e.g. statins) were strongly associated with polypharmacy. This was consistent with the findings of Bronskill et al. [5], who reported that five of the ten most prevalent medications in LTCFs were cardiovascular medications. Clinical practice guidelines provide limited guidance for the management of chronic disease among people with multimorbidity in the LTCF setting [28]. Polypharmacy may arise because clinicians extrapolate evidence from disease-specific research conducted among younger people in community settings.

This is particularly the case for cardiovascular guidelines, which provide limited guidance for older people [29, 30].

Almost three-quarters (71.7%) of residents with polypharmacy were prescribed a medication for GORD, primarily proton-pump inhibitors (PPIs). Recent studies in the USA have found almost half of residents are prescribed a PPI without an evidence-based indication [31, 32]. This is a concern because frail older residents may be particularly susceptible to harms associated with the long-term use of PPIs, including fractures, pneumonia and vitamin and mineral deficiencies [33]. There is a need for regular review of PPIs in LTCFs with a view to cease treatment in residents without an ongoing therapeutic need [34].

Residents with polypharmacy were less likely to have a dementia diagnosis or use antipsychotics. This was consistent with findings reported in a recent systematic review of polypharmacy in LTCFs, which found an inverse association between cognitive impairment and polypharmacy (three of four studies) [3]. Several studies have identified the need to avoid or discontinue medications that may impair cognition in people with coexisting cognitive impairment [35, 36]. The lower prevalence of polypharmacy among residents with dementia may reflect medication discontinuation or 'deprescribing' in residents with advanced dementia [37]. The high prevalence of swallowing difficulties among residents with dementia may provide an incentive for clinicians to discontinue unnecessary medications.

The high prevalence of analgesic use among residents with polypharmacy may reflect increased awareness that pain has been under-recognized and under-treated in LTCFs. The prevalence of pain may be as high as 80%, and this may explain the increasing use of analgesics over the last decade [38–40]. This study found 67% of all residents were charted paracetamol and 34% were charted an opioid regularly, which was consistent with other recent Australian studies [41, 42] but higher than reported internationally [39, 43]. Although the high prevalence of regular analgesic use suggests improved treatment of pain, its appropriateness is uncertain. Opioids were twice as prevalent among residents with polypharmacy as those without, and opioid use may necessitate co-prescribing of laxatives. The appropriateness of long-term opioid use in older people should be considered in light of potential harms, including falls and fractures, and limited evidence for safety and efficacy in frail older people [44].

Over half (63.6%) of residents with polypharmacy were prescribed antidepressants; however, fewer than half (44.2%) of residents with polypharmacy had a documented diagnosis of depression. It is possible that antidepressants were prescribed for other indications, including pain or insomnia. In contrast to a previous study [45], residents with polypharmacy in this study were less likely to be charted an antipsychotic. Antipsychotic use has been reported in up to one-third of residents with dementia in LTCFs [46, 47]. Polypharmacy was found to be inversely associated with dementia diagnosis in this study, which could partially explain the lower prevalence of antipsychotic use in residents with polypharmacy. In addition, the recognition of antipsychotic ADEs such as falls and mortality [48], and the introduction of initiatives to minimize antipsychotic use in dementia may also contribute [49–51].

4.3 Variability of Medications Contributing to Polypharmacy Across LTCFs

A wide variation in the prevalence of polypharmacy and in all medications classes, with the exception of other analgesics and antipyretics, was reported across the 27 LTCFs. However, the majority of facilities had fewer than 40 beds, which may contribute to the wide variability in medications seen across facilities. The variability seen in medications often used for symptomatic relief, such as high-ceiling diuretics, is likely to reflect variability in the degree of disability between residents. There was greater facility-to-facility variation in the use of antipsychotics, ranging from no regular use to 95% in one facility. However, the LTCFs included in our project encompassed a mix of both general and psychogeriatric aged care services. In addition to prescriber variability, a number of facility-level factors, including facility type and staffing levels, have been found to be associated with variability in antipsychotic use in LTCFs [13–16].

Between 7 and 23% of facilities fell outside the 95% control limits of the mean for the most prevalent medication classes, indicating inter-facility variability in the prescribing of these medications. The greatest variability between LTCFs was found for medications for constipation and antithrombotic agents, which were found to have 26 and 19% of facilities falling outside these control limits, respectively. Inter-facility variability in the prescribing of laxatives may be associated with differences in residents' level of disability and health status, including the ability to communicate their symptoms to staff [52]. Guidance for the use of antithrombotic agents, including the use of aspirin, is limited in older people and may require a risk versus benefit assessment in individual residents.

The facilities included in this study were relatively small, with ten facilities housing fewer than 15 residents. Facilities with a high prevalence of polypharmacy (defined as $\geq$ 50%) primarily had fewer than 20 residents and were located within the same health service. Prescribing may have been performed by a small number of GPs or a single GP. The Victorian Government DHHS has identified a number of strategies to address polypharmacy, three of which are currently being implemented [53]. These include

three new medication sub-indicators, creation of 'deprescribing scripts' to improve provider–resident communication about medication cessation, and optimizing the role of medication advisory committees.

4.4 Strengths and Limitations

It was a strength that data were obtained from all residents across 27 LTCFs in regional and rural Victoria, Australia, by trained members of the research team and nursing staff. Pilot testing of the standardized data collection tool and data extraction was performed by the research team to ensure consistency and accuracy among data collectors and extractors. Medical diagnoses were obtained from the clinical diagnoses recorded in each resident's medical records. Data obtained from medical records were dependent on complete and accurate recording by clinicians in the medical record, which may have been incomplete. We did not have access to information on individual residents' disease severity, goals of care or estimated life expectancy, which are important factors related to the pattern of prescribing in this setting.

The study was conducted in rural and regional areas and therefore the findings may not be generalizable to metropolitan settings. This study did not investigate prescriber- or facility-related (e.g. organizational culture) factors in addition to facility size, which may have contributed to the variability in polypharmacy across facilities. Additional studies are required to further explore resident-, prescriber- and facility factors that may have contributed to the variability in polypharmacy found across facilities. Funnel plots were created to account for facility size. The clinical appropriateness of polypharmacy and adherence to recommended clinical practice guidelines was not assessed in the present study and should be considered in future studies to determine whether interventions are needed to address polypharmacy. We could not determine whether the variability of polypharmacy across facilities in our study reflects suboptimal care. However, because common medications, both appropriate and potentially inappropriate, are more prevalent in residents with polypharmacy, it would be prudent to target individualized interventions to improve quality and safety to those facilities with unexplained rates of polypharmacy. Future research should focus on better understanding the risks associated with specific medications that are more prevalent in residents with polypharmacy. A recent case–control study reported that medications causing orthostatic hypotension, rather than polypharmacy itself, were associated with an increased risk of fall-related hospital admissions, although this risk was highest in residents with polypharmacy [54]. Longitudinal studies are needed to further explore the temporal change in medication use in LTCFs.

5 Conclusion

Polypharmacy is associated with a range of medications, including antithrombotic, beta-blocking and lipid-modifying agents, antidepressants, antipsychotics, analgesics, PPIs and high-ceiling diuretics. Up to 23% of facilities were found to have fallen outside the 95% control limits for the most prevalent medication classes. The majority of facilities in the study were small, which may have contributed to the wide variability in prescribing across facilities. Further studies are needed to investigate the clinical appropriateness of polypharmacy and the contribution of prescriber- and facility-related factors to the prevalence of and variability in polypharmacy. Longitudinal studies are needed to further explore changes in medication use in LTCFs over time.

Compliance with Ethical Standards

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Conflict of interest NJ, KMJ, ECKT, MJD, CMK and JSB have no conflicts of interest.

References

1. Thomson MS, Gruneir A, Lee M, Baril J, Field TS, Gurwitz JH, et al. Nursing time devoted to medication administration in long-term care: clinical, safety, and resource implications. J Am Geriatr Soc. 2009;57(2):266–72.
2. Payne RA, Avery AJ. Polypharmacy: one of the greatest prescribing challenges in general practice. Br J Gen Pract. 2011;61(583):83–4.
3. Jokanovic N, Tan EC, Dooley MJ, Kirkpatrick CM, Bell JS. Prevalence and factors associated with polypharmacy in long-term care facilities: a systematic review. J Am Med Dir Assoc. 2015;16(6):535.e1–12.
4. Beloosesky Y, Nenaydenko O, Gross Nevo RF, Adunsky A, Weiss A. Rates, variability, and associated factors of polypharmacy in nursing home patients. Clin Interv Aging. 2013;8:1585–90.
5. Bronskill SE, Gill SS, Paterson JM, Bell CM, Anderson GM, Rochon PA. Exploring variation in rates of polypharmacy across long term care homes. J Am Med Dir Assoc. 2012;13(3):309.e15–21.

6. Lalic S, Sluggett JK, Ilomaki J, Wimmer BC, Tan EC, Robson L, et al. Polypharmacy and medication regimen complexity as risk factors for hospitalization among residents of long-term care facilities: a prospective cohort study. J Am Med Dir Assoc. 2016;17(11):1067.e1–.e6.
7. Tamura BK, Bell CL, Inaba M, Masaki KH. Outcomes of polypharmacy in nursing home residents. Clin Geriatr Med. 2012;28(2):217–36.
8. Australian Institute of Health and Welfare. Residential aged care in Australia 2010–11: a statistical overview. 2012.
9. Lavan AH, Gallagher P. Predicting risk of adverse drug reactions in older adults. Ther Adv Drug Saf. 2016;7(1):11–22.
10. Australian Commission on Safety and Quality in Health Care. Australian atlas of healthcare variation. 2015.
11. Australian Commission on Safety and Quality in Health Care and Australian Institute of Health and Welfare. Exploring healthcare variation in Australia: analyses resulting from an OECD study. 2014.
12. Scott IA, Hilmer SN, Reeve E, Potter K, Le Couteur D, Rigby D, et al. Reducing inappropriate polypharmacy: the process of deprescribing. JAMA Intern Med. 2015;175(5):827–34.
13. Chen Y, Briesacher BA, Field TS, Tjia J, Lau DT, Gurwitz JH. Unexplained variation across US nursing homes in antipsychotic prescribing rates. Arch Intern Med. 2010;170(1):89–95.
14. Kleijer BC, van Marum RJ, Frijters DH, Jansen PA, Ribbe MW, Egberts AC, et al. Variability between nursing homes in prevalence of antipsychotic use in patients with dementia. Int Psychogeriatr. 2014;26(3):363–71.
15. Tjia J, Field T, Lemay C, Mazor K, Pandolfi M, Spenard A, et al. Antipsychotic use in nursing homes varies by psychiatric consultant. Med Care. 2014;52(3):267–71.
16. Frankenthal D, Zandman-Goddard G, Ben-Muvhar Y, Porat-Katz BS. The impact of facility characteristics on the use of antipsychotic medications in nursing homes: a cross-sectional study. Isr J Health Policy Res. 2016;5:12.
17. Australian Institute of Health and Welfare. Aged care. 2017. http://www.aihw.gov.au/aged-care/. Accessed 12 Oct 2017.
18. Sanford AM, Orrell M, Tolson D, Abbatecola AM, Arai H, Bauer JM, et al. An international definition for "nursing home". J Am Med Dir Assoc. 2015;16(3):181–4.
19. Regional Development Victoria. Region descriptions. 2015. http://www.rdv.vic.gov.au/information-portal/more-information/region-descriptions-and-geography-structure. Accessed 12 Oct 2017.
20. Sluggett JK, Ilomaki J, Seaman KL, Corlis M, Bell JS. Medication management policy, practice and research in Australian residential aged care: current and future directions. Pharmacol Res. 2017;116:20–8.
21. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40(5):373–83.
22. Buntinx F, Niclaes L, Suetens C, Jans B, Mertens R, Van den Akker M. Evaluation of Charlson's comorbidity index in elderly living in nursing homes. J Clin Epidemiol. 2002;55(11):1144–7.
23. Tan EC, Visvanathan R, Hilmer SN, Vitry AI, Quirke T, Emery T, et al. Analgesic use, pain and daytime sedation in people with and without dementia in aged care facilities: a cross-sectional, multisite, epidemiological study protocol. BMJ Open. 2014;4(6):e005757.
24. Department of Health and Human Services. Quality indicators in public sector residential aged care services: resource materials. 2015.
25. WHO Collaborating Centre for Drug Statistics Methodology. Anatomical Therapeutic Chemical (ATC) Classification Index. 2015.
26. R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2015.
27. Storms H, Marquet K, Aertgeerts B, Claes N. Prevalence of inappropriate medication use in residential long-term care facilities for the elderly: a systematic review. Eur J Gen Pract. 2017;23(1):69–77.
28. Cox L, Kloseck M, Crilly R, McWilliam C, Diachun L. Underrepresentation of individuals 80 years of age and older in chronic disease clinical practice guidelines. Can Fam Physician. 2011;57(7):e263–9.
29. Jansen J, McKinn S, Bonner C, Irwig L, Doust J, Glasziou P, et al. Systematic review of clinical practice guidelines recommendations about primary cardiovascular disease prevention for older adults. BMC Fam Pract. 2015;16:104.
30. Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, Colvin MM, et al. 2016 ACC/AHA/HFSA focused update on new pharmacological therapy for heart failure: an update of the 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Failure Society of America. J Am Coll Cardiol. 2016;68(13):1476–88.
31. Rane PP, Guha S, Chatterjee S, Aparasu RR. Prevalence and predictors of non-evidence based proton pump inhibitor use among elderly nursing home residents in the US. Res Social Adm Pharm. 2016. https://doi.org/10.1016/j.sapharm.2016.02.012 **(Epub 2016 Mar 8)**.
32. Patterson Burdsall D, Flores HC, Krueger J, Garretson S, Gorbien MJ, Iacch A, et al. Use of proton pump inhibitors with lack of diagnostic indications in 22 Midwestern US skilled nursing facilities. J Am Med Dir Assoc. 2013;14(6):429–32.
33. Desilets AR, Asal NJ, Dunican KC. Considerations for the use of proton-pump inhibitors in older adults. Consult Pharm. 2012;27(2):114–20.
34. Sluggett JK, Hendrix I, Bell JS. Evidence-based deprescribing of proton pump inhibitors in long-term care. Res Social Adm Pharm. 2017. https://doi.org/10.1016/j.sapharm.2017.04.001 **(Epub 12/04/17)**.
35. Huey ED, Taylor JL, Luu P, Oehlert J, Tinklenberg JR. Factors associated with use of medications with potential to impair cognition or cholinesterase inhibitors among Alzheimer's disease patients. Alzheimers Dement. 2006;2(4):314–21.
36. Weston AL, Weinstein AM, Barton C, Yaffe K. Potentially inappropriate medication use in older adults with mild cognitive impairment. J Gerontol A Biol Sci Med Sci. 2010;65(3):318–21.
37. Holmes HM, Sachs GA, Shega JW, Hougham GW, Cox Hayley D, Dale W. Integrating palliative medicine into the care of persons with advanced dementia: identifying appropriate medication use. J Am Geriatr Soc. 2008;56(7):1306–11.
38. Takai Y, Yamamoto-Mitani N, Okamoto Y, Koyama K, Honda A. Literature review of pain prevalence among older residents of nursing homes. Pain Manag Nurs. 2010;11(4):209–23.
39. Sandvik R, Selbaek G, Kirkevold O, Husebo BS, Aarsland D. Analgesic prescribing patterns in Norwegian nursing homes from 2000 to 2011: trend analyses of four data samples. Age Ageing. 2016;45(1):54–60.
40. Tan EC, Jokanovic N, Koponen MP, Thomas D, Hilmer SN, Bell JS. Prevalence of analgesic use and pain in people with and without dementia or cognitive impairment in aged care facilities: a systematic review and meta-analysis. Curr Clin Pharmacol. 2015;10(3):194–203.
41. Veal FC, Bereznicki LR, Thompson AJ, Peterson GM. Pharmacological management of pain in Australian aged care facilities. Age Ageing. 2014;43(6):851–6.

42. Tan EC, Visvanathan R, Hilmer SN, Emery T, Robson L, Vitry AI, et al. Analgesic use and daytime sleepiness in residents with and without dementia in residential aged care facilities. Drugs Aging. 2015;32(12):1045–53.
43. Pitkala KH, Juola AL, Hosia H, Teramura-Gronblad M, Soini H, Savikko N, et al. Eight-year trends in the use of opioids, other analgesics, and psychotropic medications among institutionalized older people in Finland. J Am Med Dir Assoc. 2015;16(11):973–8.
44. McLachlan AJ, Bath S, Naganathan V, Hilmer SN, Le Couteur DG, Gibson SJ, et al. Clinical pharmacology of analgesic medicines in older people: impact of frailty and cognitive impairment. Br J Clin Pharmacol. 2011;71(3):351–64.
45. Gellad WF, Aspinall SL, Handler SM, Stone RA, Castle N, Semla TP, et al. Use of antipsychotics among older residents in VA nursing homes. Med Care. 2012;50(11):954–60.
46. Westbury JL, Jackson S, Peterson GM. Psycholeptic use in aged care homes in Tasmania, Australia. J Clin Pharm Ther. 2010;35(2):189–93.
47. Kamble P, Chen H, Sherer JT, Aparasu RR. Use of antipsychotics among elderly nursing home residents with dementia in the US: an analysis of National Survey Data. Drugs Aging. 2009;26(6):483–92.
48. Huybrechts KF, Rothman KJ, Silliman RA, Brookhart MA, Schneeweiss S. Risk of death and hospital admission for major medical events after initiation of psychotropic medications in older adults admitted to nursing homes. CMAJ. 2011;183(7):E411–9.
49. National Prescribing Service. Antipsychotic overuse in dementia—is there a problem? 2013. http://www.nps.org.au/publications/health-professional/health-news-evidence/2013/antipsychotic-dementia. Accessed 14 Nov 2016.
50. National Prescribing Service. Quality use of antipsychotics for behavioural and psychological symptoms of dementia. 2013. http://www.agedcare.nps.org.au/clinical_info/feature_topics/topics/antipsychotic_therapy_for_behavioural_and_psychological_symptoms_of_dementia/aged-care-qum-reports. Accessed: 14 Nov 2016.
51. Westbury J, Jackson S, Gee P, Peterson G. An effective approach to decrease antipsychotic and benzodiazepine use in nursing homes: the RedUSe project. Int Psychogeriatr. 2010;22(1):26–36.
52. Blekken LE, Nakrem S, Vinsnes AG, Norton C, Morkved S, Salvesen O, et al. Constipation and laxative use among nursing home patients: prevalence and associations derived from the residents assessment instrument for long-term care facilities (interRAI LTCF). Gastroenterol Res Pract. 2016. https://doi.org/10.1155/2016/1215746 **(Epub 2016 Jan 17)**.
53. Jokanovic N, Wang KN, Dooley MJ, Lalic S, Tan EC, Kirkpatrick CM, et al. Prioritizing interventions to manage polypharmacy in Australian aged care facilities. Res Social Adm Pharm. 2017;13(3):564–74.
54. Ryan-Atwood TE, Hutchinson-Kern M, Ilomaki J, Dooley MJ, Poole SG, Kirkpatrick CM, et al. Medication use and fall-related hospital admissions from long-term care facilities: a hospital-based case-control study. Drugs Aging. 2017;34(8):625–633.