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Development and validation of PolyScan, an information technology triage tool for older adults with polypharmacy: a healthcare informatics study

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ABSTRACT

Introduction. Polypharmacy is associated with potentially inappropriate medicine prescribing and avoidable medicine-related harm. Polypharmacy should not be perceived as inherently harmful. Instead, priority should be placed on reducing inappropriate prescribing. **Aim.** The study aimed to develop and validate PolyScan, a primary care information technology tool, to triage older adults with polypharmacy who are prescribed potentially inappropriate medicines. **Methods.** Twenty-one indicators from a New Zealand criteria of potentially inappropriate medicines to correct for older adults with polypharmacy were developed into a set of implementable definitions. The definitions were applied as algorithmic logic statements used to interrogate hospital and emergency department records and pharmaceutical collection data to classify whether each indicator was present at an individual patient level, and then triage individuals based on the number of indicators met. Validity was evaluated by comparing PolyScan's accuracy against a manual review of healthcare records for 300 older adults. **Results.** PolyScan was successfully implemented as a tool that can be used to identify potentially inappropriate prescribing in older adults with polypharmacy at different levels of aggregation. The tool has utility for individual practitioners delivering patient care, primary care organisations undertaking quality improvement programmes, and policymakers considering system-level interventions for medicines-related safety. During the validity assessment, PolyScan identified nine individuals (3%) with polypharmacy and indicators of potentially inappropriate medicine. Five unique indicators were detected. PolyScan achieved 100% sensitivity, specificity, and positive and negative predictive values. **Discussion.** PolyScan can support clinicians, clinics, and policymakers with allocation of resources, rational medicine campaigns, and identifying individuals prescribed potentially inappropriate medicines for review.

Keywords: aged, health informatics, inappropriate prescribing, medical informatics, pharmaceutical preparations, polypharmacy, primary health care, triage.

Introduction

Polypharmacy is the prescribing of multiple medicines to an individual.[1] Polypharmacy can be appropriate when individuals with comorbidities are prescribed medicines according to best practice evidence. However, problematic polypharmacy can occur if medicines are prescribed inappropriately.[1]

Problematic polypharmacy presents a particular challenge for older adults. On average, older adults are more likely to acquire co-morbidities and be treated with more medicines, of which some may be inappropriate.[1,2] Additionally, there is an increased risk of medicines-related harm due to age-related changes to physiology affecting medicine pharmacodynamics and pharmacokinetics.

Numerical thresholds have been used to define polypharmacy, with up to 11 or more medicines cited.[3] However, a greater number of medicines should not be considered as invariably harmful. For example, in Payne *et al.*'s study, the risk of unplanned hospital

WHAT GAP THIS FILLS

What is already known: Polypharmacy is common in older adults, and while not inherently unsafe, can be associated with increased adverse medicine events. There is a need for reliable and effective approaches to systematically triage those most at risk of adverse medicine events who may benefit from intervention.

What this study adds: PolyScan is an information technology tool that has been developed and validated for New Zealand, based on an explicitly derived set of criteria. PolyScan can identify and triage older adults with polypharmacy in primary care who have been prescribed potentially inappropriate medicines.

admission for individuals with multiple co-morbidities taking four to six medicines was comparable to those taking one to three (odds ratio 1.00; 95% confidence interval 0.88–1.14).[4] To reduce problematic polypharmacy, a medication review is necessary to reduce potentially inappropriate medicine (PIM)-related harm.[5,6] Unfortunately, due to limited clinician resources, individuals prescribed PIMs may not always be promptly identified for review.

In New Zealand, primary care is central to the delivery of health services. Additionally, as general practice clinics and pharmacies mostly prescribe and dispense medicines electronically, there is extensive data documenting medicine use.[7] Therefore, a potential exists to design information technology (IT) tools that analyse data to support clinicians reviewing individuals with problematic polypharmacy.

Published research of IT tools to address problematic polypharmacy in New Zealand is limited. For example, the NZ Criteria and the Pill Pruner project identified indicators of PIM use to guide medication review for individuals with polypharmacy.[8,9] However, the NZ Criteria and Pill Pruner project were not developed as IT tools. In contrast, a sole protocol from Young *et al.* describes plans for an IT tool to assist prescribers in reviewing individuals with polypharmacy.[10]

In 2019, an IT tool was developed in the New Zealand MidCentral region to identify older adults with polypharmacy based on a numerical threshold of medicines dispensed. Although the tool provided clinicians with a relatively simple means of selecting individuals for review, it was unable to direct clinicians to individuals at the greatest risk of PIM-related harm.

To effectively utilise clinician resources to reduce problematic polypharmacy, a tool is required to identify and triage individuals with polypharmacy (taking 11 or more long-term medicines) prescribed PIMs to be at 'the right place, at the right time, to receive the right level of care'.[11] The objective of this study is to develop and validate PolyScan, an IT triage tool for use in primary care.

Methods

Contextual background

As described above, Te Whatu Ora MidCentral District developed an IT tool to support pharmacists in the New Zealand MidCentral region with medication reviews. The MidCentral tool was used to identify individuals aged 65 years and over with polypharmacy (dispensed 11 or more long-term medicines).

The tool analysed data from the New Zealand Pharmaceutical Collection to identify a long-term medicine as the same medicine dispensed in two consecutive 3-month quarters. The New Zealand Ministry of Health defines the Pharmaceutical Collection as 'a data warehouse that supports the management of pharmaceutical subsidies. It contains claim and payment information from pharmacists for subsidised dispensings'.[7]

PolyScan was developed and implemented in collaboration with Te Whatu Ora MidCentral District as a further development to the existing MidCentral tool.

Development of PolyScan

Programing data sources

PolyScan was programed in Qlik Sense software (version 13.82.14) by Qlik® to analyse data from the Unique Dispensing Identification file and Formulation file of the Pharmaceutical Collection database. In addition, PolyScan searches International Statistical Classification of Diseases and Related Health Problems 10th revision (ICD-10) codes, SNOMED CT New Zealand Edition codes, and keywords from diagnosis descriptions in hospital and emergency department (ED) free-text records (Fig. 1).

The Pharmaceutical Collection comprises distinct tables linked in a relational database. Technical information on the database structure can be found in the Pharmaceutical Information Database data guide.[12] Pharmaceutical dispensing claim data, including medicine supplied, dosage, date, and duration of supply, are linked via the patient's National Health Index identifier number. ICD-10 is a clinical classification system for diseases.[13] SNOMED CT New Zealand Edition is a clinical terminology system for New Zealand electronic healthcare records.[14]

Converting NZ Criteria indicators into machine-readable definitions

In 2022, a criterion of PIMs to correct for older adults with polypharmacy was published. The NZ Criteria represent 61 indicators that New Zealand healthcare experts agree should prompt caution for older adults with polypharmacy.[8]

From the NZ Criteria, 21 indicators identified as very important to correct were categorised into combinations of 'medicine', 'dosage, 'pharmacologic class', and 'diagnosis' machine-readable definitions (Table 1).

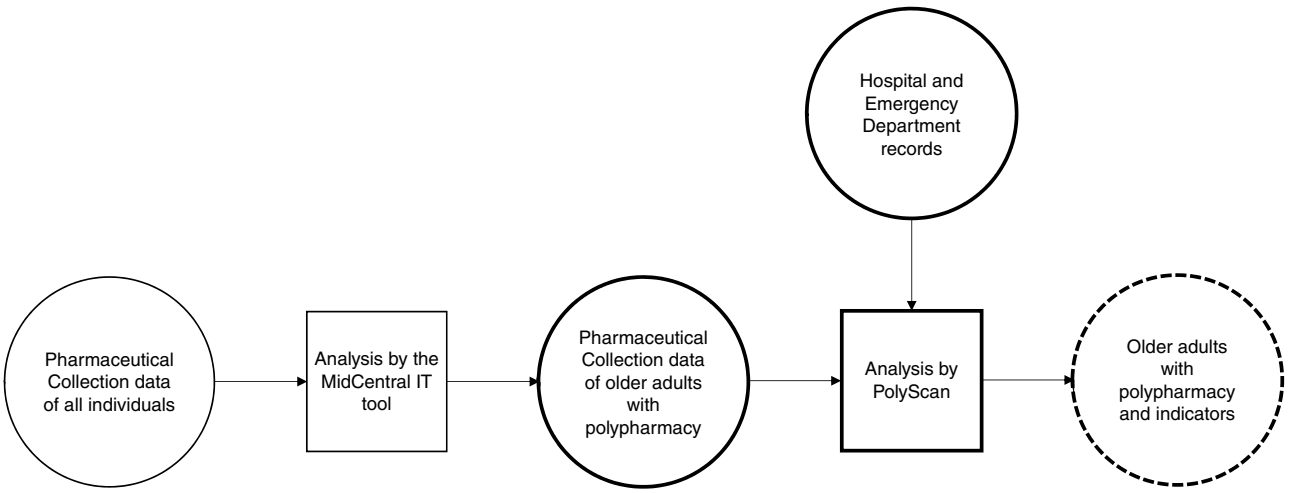


Fig. 1. Process to identify older adults with polypharmacy and indicators.

PolyScan searches ICD-10 codes, SNOMED CT New Zealand Edition codes, and diagnosis description keywords from hospital and ED records for individuals with 'diagnosis' definitions.

PolyScan searches the Pharmaceutical Collection database for individuals with 'medicine', 'dosage, and 'pharmacologic class' definitions.

- Medicines are searched in the Chemical Name category of the Formulation file.
- The commercially available dosages of medicines are searched in the Formulation Name category of the Formulation file.
- Pharmacologic classes are searched in the Therapeutic Group categories of the Formulation file.

Incorporating data from the MidCentral IT tool

The output from the existing MidCentral tool, in the form of most current Pharmaceutical Collection data of older adults with polypharmacy (individuals aged 65 years and over dispensed 11 or more long-term medicines) was delivered to PolyScan for analysis.

Identifying older adults with polypharmacy who meet indicators

PolyScan searched the MidCentral tool output to identify individuals who met an indicator. To do so, the decision logic identified the presence of 'medicine', 'dosage', 'pharmacologic class', and 'diagnosis' definitions as input variables, and whether an individual met the indicator as the output variable. PolyScan then tallied and ranked individuals based on the number of indicators met to produce a priority sequence.

Validation of PolyScan

PolyScan's sensitivity, specificity, and accuracy were examined by statistical analysis. Accuracy was compared to a manual review, applying the 21 selected indicators, developed as described by Liu *et al.* to represent the gold standard.[8] PolyScan was applied to 300 de-identified individuals aged 65years or older. The author (LL) then manually reviewed Pharmaceutical Collection, ICD-10, and SNOMED CT New Zealand Edition records. The performance of PolyScan to identify older adults with polypharmacy who met indicators was calculated as sensitivity, specificity, and positive and negative predictive values.

Ethics approval

The study adhered to the Declaration of Helsinki principles and received approval from the Auckland Health Research Ethics Committee (AH3396), Health and Disability Ethics Committees (20/STH/238), and Te Whatu Ora MidCentral District (2021.01.011).

Results

PolyScan output

PolyScan is a Qlik® dashboard for older adults with polypharmacy. PolyScan presents different views of the output data as four reports depending on the task that the end user is engaged in (Fig. 2).

The 'PIM indicators ranked by the number of patients identified' reports data on the most commonly detected indicators. The report enables healthcare policymakers such as primary health organisations to monitor the prescribing trends of PIMs across the region for system-level intervention.

The 'Prescriber ranked by the number of patients identified' report can rank prescribers by the number of individuals under their care prescribed PIMs. The 'Prescriber patient list ranked by the number of PIM indicators

Table 1. Categorisation of indicators.

Indicator	Categorisation	Description
Any combination of ≥ three CNS active medications such as antidepressants, antipsychotics, antiepileptics, benzodiazepines, 'Z' drugs, opioids.	(Pharmacologic class: antidepressants OR antipsychotics OR antiepilepsy drugs OR anxiolytics OR sedatives and hypnotics OR opioid analgesics)	Combination of three or more medicines from the specified pharmacologic classes dispensed in the same 3-month quarter
	AND NOT	AND NOT
	(Medicine: Buspirone OR Phenobarbitone OR Melatonin)	Multiple medicines
Long-acting sulfonylureas, eg glibenclamide (glyburide).	(Medicine: Glibenclamide)	Medicine
Alpha blockers in the elderly with postural hypotension problems.	(Pharmacologic class: alpha adrenoceptor blockers OR alpha-1A adrenoreceptor blockers)	Multiple pharmacologic classes
	AND	AND
	(Diagnosis: postural hypotension OR orthostatic hypotension)	Multiple diagnosis
NSAIDs in older adults with renal impairment or chronic kidney disease stage 4 or higher.	(Pharmacologic class: non-steroidal anti-inflammatory drugs)	Pharmacologic class
	AND	AND
	(Diagnosis: renal impairment OR chronic kidney disease stage 4 OR chronic kidney disease stage 5)	Multiple diagnosis
Triple whammy interaction.	(Pharmacologic class: ACE inhibitors OR angiotensin II antagonists)	Combination of three medicines from the specified pharmacologic classes dispensed in the same 3-month quarter
	AND	
	(Pharmacologic class: diuretics)	
	AND	
	(Pharmacologic class: non-steroidal anti-inflammatory drugs)	
Amiodarone as first line treatment in atrial fibrillation without diagnosis of substantial left ventricular hypertrophy or heart failure.	(Medicine: Amiodarone)	Medicine
	AND	AND
	(Diagnosis: atrial fibrillation)	Diagnosis
	AND NOT	AND NOT
	(Diagnosis: heart failure OR left ventricular hypertrophy)	Multiple diagnosis
Tricyclics or quetiapine for sleep.	(Pharmacologic class: cyclic and related agents OR Medicine: Quetiapine)	Pharmacologic class OR medicine
	AND	AND
	(Diagnosis: insomnia OR sleep)	Multiple diagnosis
Insulin regimens with only short or rapid-acting insulin dosed based on current blood glucose levels without concomitant use of basal or long-acting insulin.	(Pharmacologic class: Insulin – rapid acting preparations OR Insulin – short acting preparations)	Multiple pharmacologic classes
	AND NOT	AND NOT
	(Pharmacologic class: Insulin – intermediate-acting preparations OR Insulin – long-acting preparations)	Multiple pharmacologic classes
Non-COX-2 selective NSAIDs in older adults with history of gastric or duodenal ulcers.	(Pharmacologic class: non-steroidal anti-inflammatory drugs)	Pharmacologic class
	AND NOT	AND NOT

(*Continued on next page*)

Table 1. (*Continued*)

Indicator	Categorisation	Description
	(Medicine: Meloxicam OR Celecoxib OR Etoricoxib OR Parecoxib)	Multiple medicines
	AND	AND
	(Diagnosis: gastric ulcer OR duodenal ulcer)	Multiple diagnosis
Persistence of strong opioids in acute pain.	(Medicine: Morphine OR Oxycodone OR Fentanyl OR Methadone OR Pethidine)	Multiple medicines
	AND	AND
	(Diagnosis: acute pain)	Diagnosis
Combination antiplatelets with anticoagulants in stable heart disease.	(Pharmacologic class: antiplatelet agents)	Multiple pharmacologic classes
	AND	AND
	(Pharmacologic class: oral anticoagulants)	Multiple diagnosis
	AND	
	(Diagnosis: cardiovascular disease OR heart disease)	
Multiple antihypertensives in frailty.	(Pharmacologic class: ACE inhibitors OR angiotensin II antagonists OR calcium channel blockers OR diuretics[A] OR alpha adrenoceptor blockers OR beta adrenoceptor blockers OR centrally acting agents OR vasodilators)	Combination of two or more medicines from any of the specified pharmacologic classes dispensed in the same quarter
	AND	AND
	(Diagnosis: frailty)	Diagnosis
Digoxin as first line therapy of heart failure or atrial fibrillation.	(Medicine: Digoxin)	Medicine
	AND	AND
	(Diagnosis: heart failure OR atrial fibrillation)	Multiple diagnosis
Antipsychotics in older adults with cognitive impairment, or dementia without a target behaviour identified.	(Pharmacologic class: antipsychotics)	Pharmacologic class
	AND	AND
	(Diagnosis: cognitive impairment OR dementia)	Multiple diagnosis
Aspirin (> 325 mg/day) in older adults with history of gastric or duodenal ulcers.	(Medicine: Aspirin)	Medicine
	AND	AND
	(Dosage: ≥ 300 mg/day)[B]	Dosage
	AND	AND
	(Diagnosis: gastric ulcer OR duodenal ulcer)	Multiple diagnosis
Clonidine as first line treatment of hypertension.	(Medicine: Clonidine)	Medicine
	AND	AND
	(Diagnosis: hypertension)	Diagnosis
RAS inhibitor (ACEi, ARB) or potassium sparing diuretic prescribed with another RAS inhibitor in older adults with chronic kidney disease stage 3a or greater.	(Pharmacologic class: ACE inhibitors OR angiotensin II antagonists OR potassium sparing diuretics)	Multiple pharmacologic classes
	AND	AND
	(Pharmacologic class: ACE inhibitors OR angiotensin II antagonists)	Multiple pharmacologic classes
	AND	AND

(*Continued on next page*)

Table 1. (*Continued*)

Indicator	Categorisation	Description
	(Diagnosis: chronic kidney disease stage 3 OR chronic kidney disease stage 4 OR chronic kidney disease stage 5)	Multiple diagnosis
Antipsychotics in older adults with history of falls or fractures.	(Pharmacologic class: antipsychotics)	Pharmacologic class
	AND	AND
	(Diagnosis: fall OR fracture)	Multiple diagnosis
Antipsychotics (except quetiapine, clozapine) in older adults with Parkinson's disease.	(Pharmacologic class: antipsychotics)	Pharmacologic class
	AND NOT	AND NOT
	(Medicine: Quetiapine OR Clozapine)	Multiple medicines
	AND	AND
	(Diagnosis: Parkinson's disease)	Diagnosis
NSAIDs and COX-2 inhibitors in older adults with heart failure.	(Pharmacologic class: non-steroidal anti-inflammatory drugs)	Pharmacologic class
	AND	AND
	(Diagnosis: heart failure)	Diagnosis
Opioids prescribed with benzodiazepines or Gabapentin, Pregabalin.	(Pharmacologic class: opioid analgesics)	Pharmacologic class
	AND	AND
	(Medicine: Clobazam OR Clonazepam OR Diazepam OR Lorazepam OR Temazepam OR Triazolam OR Midazolam OR Gabapentin OR Pregabalin)	Multiple medicines

Abbreviations: CNS, central nervous system; NSAID, non-steroidal anti-inflammatory drug; RAS, renin-angiotensin system; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; COX-2, cyclooxygenase-2.
[A]The keyword 'diuretics' was searched in all therapeutic group categories of the Pharmaceutical Collection Formulation file.
[B]Extracting the dosage 'aspirin > 325 mg' from Pharmaceutical Collection Formulation file was not feasible. Therefore, PolyScan searched for the commercially available aspirin 300 mg dosage.

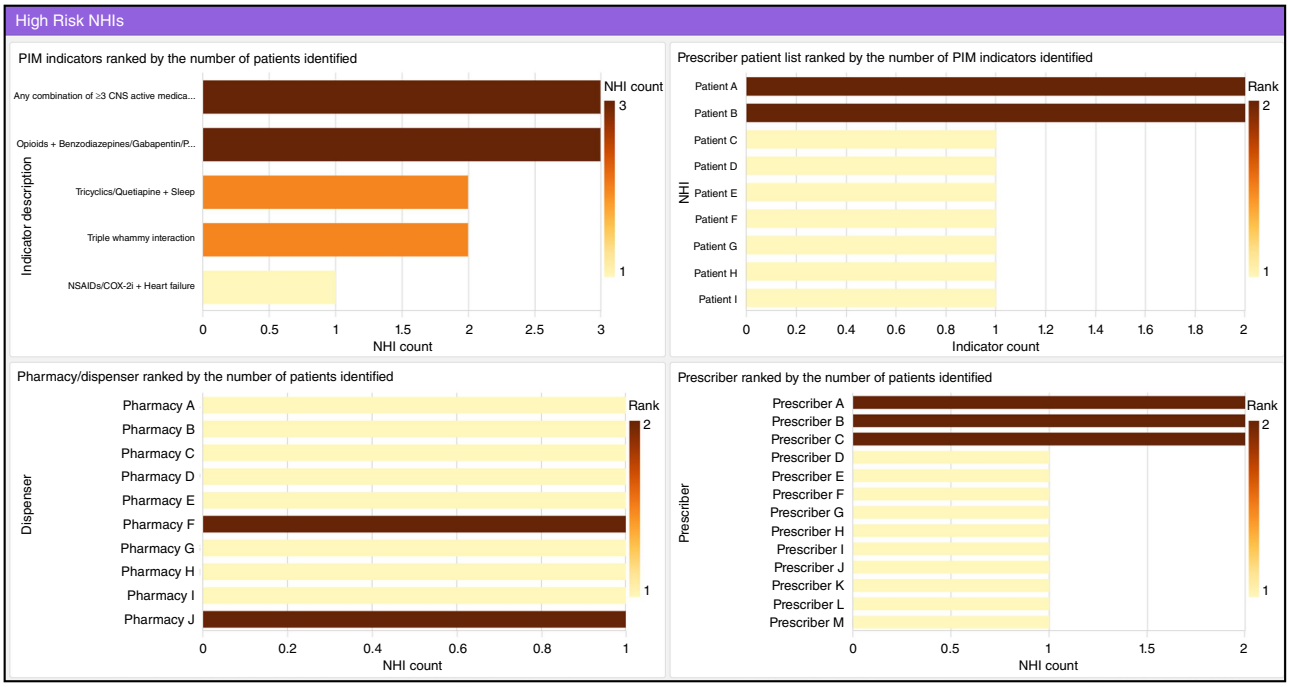
identified' reports on the individuals that prescribers have prescribed PIMs. The report can identify and rank individuals by the number of indicators detected. Additionally, PolyScan can identify which indicators were detected and the dispensing pharmacy. General practice management can use these two reports to measure the number of clinic individuals that have received PIMs. Prescribers can also invite individuals under their care who were prescribed PIMs to receive a medication review and track their prescribing trends over time.

The 'Pharmacy/dispenser ranked by the number of patients identified' report can rank pharmacies by the number of individuals that were dispensed PIMs. Additionally, PolyScan can identify specific individuals, the detected indicators, and the prescriber. Pharmacists can use the report to invite individuals from their pharmacy that were dispensed a PIM to receive a pharmacist-facilitated medication review.

Validation statistics

PolyScan achieved 100% sensitivity, specificity, and positive and negative predictive values (Table 2). PolyScan identified nine individuals (3%) with polypharmacy who met indicators, and 291 individuals (97%) who were not polypharmacy or did not meet indicators from 300 older adults screened. When compared to the manual review, of the nine individuals with polypharmacy who met indicators, nine were true positives, and zero were false negatives. Among the 291 individuals that were not polypharmacy or did not meet indicators, 291 were true negatives, and zero were false positives.

The individuals identified by PolyScan met one or more indicators. In total, five unique indicators were detected. The indicators 'Any combination of ≥ three CNS active medications such as antidepressants, antipsychotics, antiepileptics, benzodiazepines, 'Z' drugs, opioids', and 'Opioids prescribed with benzodiazepines or Gabapentin, Pregabalin' were each observed in 33% of identified individuals ($n = 3$). The indicators 'Triple whammy interaction', and 'Tricyclics or quetiapine for sleep' were each observed in 22% of individuals ($n = 2$). The indicator 'NSAIDS and COX-2 inhibitors in older adults with heart failure' was observed in 11% of individuals ($n = 1$).



Abbreviations: PIM, potentially inappropriate medicine; NHI, National Health Index.
[A]Identifiable patient, pharmacy, and prescriber information have been concealed.

Fig. 2. The PolyScan dashboard.[A]

Table 2. 3 × 3 Contingency table comparing the performance of PolyScan against a manual review.

	Polypharmacy and dispensed an indicator	Not polypharmacy or not dispensed an indicator	Row total (PolyScan)
Screen positive	9	0	9
Screen negative	0	291	291
Column total (manual review)	9	291	300

Discussion

There is interest in whether IT tools can be used to support individuals with polypharmacy. This study describes the development and validation of PolyScan, an IT tool for primary care, which can triage older adults with polypharmacy at risk of PIM prescribing. PolyScan was validated with 100% sensitivity, specificity, and positive and negative predictive values.

This study adds to the body of research into IT tools used to address PIM prescribing. Studies of related tools can be broadly categorised as computerised clinical decision support, and electronic audit and feedback. The approach to developing computerised clinical decision support is through generating computer-assisted alerts, guidelines, or reminders when PIMs are prescribed, to assist clinicians to reach patient care decisions.[15,16] In comparison, the approach to developing electronic audit and feedback is providing clinicians with electronic summaries of their clinical performance over time.[17] Studies of computerised clinical decision support and electronic audit and feedback have demonstrated the potential to reduce PIM prescribing.[18–21]

IT triage tools have been successfully used to prioritise healthcare resources for individuals with the greatest need.[22,23] However, currently, no studies of IT triage tools for individuals with polypharmacy and PIM prescribing have been identified. This study describes the development of what is thought to be a novel tool.

During the validation of PolyScan, 3% of older adults screened had 11 or more long-term medicines and indicators in their regimen. The finding is consistent with the Atlas of Health Care Variation report that, in 2019, 4% of New Zealand older adults were dispensed 11 or more long-term medicines.[24] The PIMs detected during validation have been widely described in the literature. The Atlas of Health Care Variation reported that, in 2019, 23.6% of New Zealand older adults were dispensed a benzodiazepine or Zopiclone and a strong opioid following a public hospital event, and 3.2% of older adults were dispensed a 'triple whammy' combination of an angiotensin-converting enzyme inhibitor

or angiotensin receptor blocker, a non-steroidal anti-inflammatory drug, and a diuretic.[2] Central nervous system active medicines can increase the risk of falls and fractures,[25] whilst a 'triple whammy' can increase the risk of acute kidney injury.[26] Additionally, there are concerns that low-dose Quetiapine is increasingly prescribed off-label for insomnia.[27] Quetiapine is associated with adverse effects, such as next-day drowsiness, with minimal evidence for its benefit as a sleeping aid.[27] Lastly, Narayan and Nishtala reported, in 2011, that 6.9% of older adults with heart failure were dispensed a non-steroidal anti-inflammatory drug or cyclooxygenase-2 inhibitor, which may exacerbate heart failure.[28,29]

A strength of PolyScan is the use of multiple data sources to identify individuals. The delivery of several outputs also increases PolyScan's utility and application for policy and practice. Furthermore, the study's design provides a template for the replication or expansion of the tool into other regions of New Zealand.

There were limitations with the data sources used for PolyScan. Firstly, PolyScan was programed to search for diagnosis descriptions from hospital and emergency department records. However, using hospital and emergency department records may not identify primary care-only diagnoses for individuals who have not presented to hospital. Secondly, PolyScan cannot identify individuals consuming potentially inappropriate over-the-counter or pharmacist-only medicines, as these are not included in the Pharmaceutical Collection database. Thirdly, the Pharmaceutical Collection database is limited in its ability to search for exact dosages of medicines.

It is acknowledged that due to access provisions, the absence of an independent evaluator could increase the risk of confirmation bias, due to the evaluating author's familiarity with the indicator set and how they work. However, it is also recognised that the evaluating author's understanding of the indicator set and expertise in medication review enabled the diligent application of the indicators to represent the gold standard.

For healthcare policymakers, PolyScan can be used to support the allocation of resources. For example, PolyScan can identify frequently prescribed PIMs, so system-level interventions and targeted education can be directed to reduce commonly observed high-risk prescribing. PolyScan can also be used to identify general practise clinics with a significant population of prescribed PIMs for additional support. For general practise clinics and pharmacies, PolyScan can support rational medicine use campaigns by identifying individuals receiving PIMs for a medication review and then measuring changes over time. Lastly, PolyScan can assist clinicians to identify and prioritise individuals under their care who have been prescribed PIMs for review.

PolyScan is currently tailored for use in the MidCentral region. Future research may expand PolyScan into other regions, or integrate it within the national healthcare system, for example, as a part of a standardised medicines-related early warning system. Further research may evaluate the potential to incorporate primary care data to improve PolyScan's sensitivity. For example, ePrescription Service data could more accurately search for medicine dosages, whilst general practise records could identify individuals who have not received secondary health care. Conceptually, PolyScan could be incorporated into the practice management software of general practise clinics to alert prescribers of PIMs in real-time, before the medicine is prescribed. Lastly, further research should evaluate whether an intervention developed using PolyScan can improve health outcomes. Ongoing work will use PolyScan to develop a primary care intervention to reduce PIM prescribing for older adults with polypharmacy.

Conclusion

Polypharmacy is an important area of healthcare risk. This study concludes that an IT tool could be used to support individuals with polypharmacy, by developing and validating PolyScan for primary care. PolyScan enables users to identify and triage older adults with polypharmacy who have been prescribed PIMs and are at risk of medicine-related harm. It is hoped policymakers, clinics, and clinicians may find PolyScan useful to improve health outcomes for individuals at risk of medicines-related harm.

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