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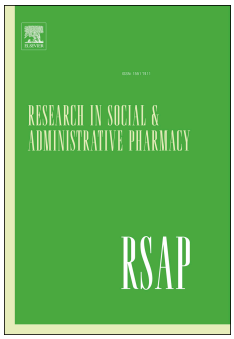

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Patient prioritization for pharmaceutical care in hospital: a systematic review of assessment tools[1]

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Abbreviations

Drug-related problems (DRPs); medication errors (MEs); adverse drug events (ADEs); adverse drug reactions (ADRs); pharmaceutical assessment screening tool (PAST); Assessment Risk Tool (ART)

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Abstract

Background: Clinical pharmacy services improve patient safety, outcomes, and care quality; however, UK clinical pharmacy services face limited resources, insufficient capacity, and patients who present with increasingly complex medication regimes and morbidities. These indicate a need for the prioritization of pharmacy services. Several prioritization tools have been developed; however, there has been no comprehensive review of such tools to date.

Objective: A systematic review was conducted to provide a structured overview and description of existing assessment tools with a focus on study quality, themes, tool validity, risk factors, and high-risk drug classes.

Methods: Systematic searches for English-language publications (from 1990 to September 2017) were conducted in Embase, Medline, Scopus, International Pharmaceutical Abstracts, and Web of Science. Papers in the inpatient setting and in which the tool users were pharmacists or pharmacy technicians were included. Data on each study (e.g. aim and design) and the structure of tools (e.g. risk factors) from each included study were extracted by 2 independent reviewers. A descriptive analysis was conducted to summarize these tools along with a thematic analysis of study findings. The quality of each paper was assessed using the Hawker method.

Results: Nineteen studies involving 17 risk assessment tools were included. Most tools were developed in Europe (76.5%) and published in the last 5 years (82%). Most tools (88%) were designed to identify patients at greatest risk of adverse drug reactions, adverse drug events, or medication errors and to guide appropriate pharmaceutical care. Ten out of 17 tools (59%) were validated. None showed a measurable impact on prescription errors or adverse drug

events. Keys themes identified from the studies were the positive impact of risk assessment tools on both patient care and provision of pharmacy services as well as the limitations of risk assessment tools.

Conclusions: Current assessment tools are heterogeneous in their content, targeting diverse patient groups and clinical settings making generalization difficult. However, an underlying theme of all studies was that tools appear to achieve their aim in directing pharmaceutical care to where it is needed most which might provide reassurance and incentive for greater adoption and development of tools across clinical pharmacy services. However, further research is required to measure objectively the impact of tools on patient outcomes and on workforce efficiency so that comparisons can be made between tools.

Keywords: pharmacy prioritization, patient safety, care quality, risk assessment, patient priority, assessment tool

Introduction

Drug-related problems (DRPs) are a major concern for policymakers and practitioners in healthcare systems globally. They place a substantial health and economic burden on both the patient and healthcare system.[1–4] DRPs could account for about 28% of patient visits to the emergency department.[5] The rate of medication related hospitalization ranges from between 2 to 5.6%.[6,7] Despite this, many DRPs can be prevented, thus reducing the length of hospital stays, associated costs, as well as morbidity and mortality.[8,9] Interventions to identify and minimize DRPs have key clinical significance in instituting prompt and effective therapeutic interventions.[10]

Clinical pharmacy services can be defined as the pharmacist led services that contribute actively to patient care in order to optimize drug therapy outcomes, these might include but are not limited to patient education, adjustment or monitoring of medication and reviews of

medication charts.[11,12] There is evidence to suggest that clinical pharmacy services improve patient safety[12,13]and that clinical pharmacists are major contributors to the identification, rectification, and prevention of DRPs[14] which can decrease the length of hospital stays.[12]

Ideally, each hospital pharmacy would have the resources to provide comprehensive clinical pharmacy services to every patient based on their needs.[15] However, pharmacy departments are faced with numerous challenges, such as reduced funding, staffing issues, which are combined with an increasing number of elderly admissions with multimorbidities and polypharmacy, and a demand for a 7-day clinical services.[15–22] This has led to more innovative approaches to service delivery, which means that comprehensive clinical pharmacy services are not provided to all patients.[15,17,21,23,24] Prioritization of clinical pharmacy services has been identified as one of the solutions for achieving cost effectiveness and increased productivity.[15,17,19,22–24] Therefore, there is a necessity to assess and prioritize patients who are in most need of input from the pharmacist. This approach would improve the delivery of clinical pharmacy services within a resource-limited healthcare service with the aim of enhancing patient care.[21]

For the early detection and prompt management of high-risk patients in clinical settings, several risk assessment tools have been developed. Several such tools exist in pharmacies and help with the assessment of patient acuity, which is defined as the ability to predict patient requirements for care.[25] These tools differ from each other concerning the target patient group (e.g., pediatrics, adult), address diverse sources of DRPs, and the setting that they were developed for (e.g., primary or secondary care).

Despite the existence of multiple tools, a comprehensive review of these instruments has yet to be undertaken. Therefore, a systematic review was conducted to provide a structured overview and description of existing assessment tools used by hospital pharmacies that assess patient priority and/or complexity with a focus on study quality, themes, tool validity, risk

factors, and high-risk drug classes. The findings of a review of current approaches to prioritization may be useful to both pharmacists and researchers who may want to compare the tools and findings or design a new tool for local needs in daily practice.

Methods

Literature search

This review follows PRISMA Guidelines for reporting systematic reviews.[26] Medline, Embase, International Pharmaceutical Abstracts, Scopus, and Web of Science electronic databases were used in the search from January 1990 to September 2017. The reference lists of all included studies were also searched manually. The search involved the use of synonyms, truncation symbols, such as an asterisk (*), as well as Boolean terms "OR" and "AND," which made the search more general or more specific, respectively. Four keywords—priority, tool, hospital, and pharmaceutical care—were used to start the search (Table 1). The keywords and their synonyms together with the Boolean operators "AND" and "OR" were used to obtain the articles. After the database search was complete, all duplicate citations were removed using Mendeley reference management software (Elsevier, 2017). Following this, the reviewer (MA) assessed publications for eligibility by title, abstract, or full text screening. Any article for which there was uncertainty regarding inclusion or exclusion was discussed between 3 authors (MA, DS, and PL) until agreement was reached.

Table 1: Search keywords

Search Keywords		
1. Priority	OR	priorit*, triage*, acuity, complex*.
2. Tool	OR	tool*, scor*, screen*, criteria, scale, classif*, assess*, clinical

		assess* tool*, instrument*, measure*, stratif*, software.
3. Hospital	OR	hospital*, secondary care.
4. Pharmaceutical care	OR	pharmacy, pharmacist*, pharmaceutical, pharmac* service*, hospital pharmac*, clinical pharmac*, clinical pharmac* service*
5. 1 AND 2 AND 3 AND 4		

Inclusion criteria

Studies where the tool users were pharmacists or pharmacy technicians were included. All age groups of patients were included in the literature review; i.e., children, adults, or the elderly. Only studies of tools used in the inpatient setting were included as the acuity of patients and the clinical services offered by pharmacies differ substantially in other settings such as community pharmacies or hospital outpatients.

Studies using quantitative, qualitative, or mixed methodology; published reviews; as well as conference abstracts with sufficient detail related to the tool description were included in the search. In general, as the definition of pharmaceutical care was first introduced in 1990, all the studies published since that date until the date of the search (updated on November 30, 2017) were included in the review.

Exclusion criteria

Papers written in languages other than English were excluded because analyzing and describing the tools required a complete understanding of the text.

Data extraction and quality assessment

To achieve consistency, reduce bias, and ensure the extracted data were valid, standardized data extraction forms were developed and used. The data extracted from the studies included the author, the country, study aim, design, duration, sample size, population group, tool type, tool benefits, tool limitations, study limitations, and tool validity. For each study, data were extracted by 2 of the authors independently (MA and PL), with any disagreements in extraction being resolved by discussion between all authors (MA, DS, and PL)).

A thematic analysis was conducted with data collected from the included articles. Overarching themes were iteratively and inductively identified using the following steps: the articles were read to gain familiarization and understanding of their content.[27] Following this, a list of key ideas was generated and grouped; these were then coded in the articles using distinct colored highlighters to indicate potential patterns. Codes were grouped together into categories. The initial codes and categories were reviewed and agreed by the authors, after which they were applied in each included paper. Before the data were entered into the framework matrix using an Excel spreadsheet, the data had been summarized. Once all the data were coded, the codes were sorted into the overarching themes. Finally, the identified themes were collated and analyzed to interpret the underlying meanings, which were labelled as subthemes. The thematic analysis was performed by two authors (MA and PL). During all stages there were repeated discussions between all authors (MA, DS, and PL) of the overall interpretation of the data.

The quality of included papers was assessed by MA using the quality assessment tool by Hawker and colleagues.[28] It is considered appropriate for use in this review because it appraises disparate publication papers, accounting for qualitative, quantitative, review articles, and conference abstracts. In addition, it is more consistent to use this checklist, as

opposed to individual checklists for each type of study. Furthermore, the 9-item checklist allows the researcher to quantify and score results, thus enabling comparison of quality between publication papers to identify areas that are weak/strong.

Hawker's assessment tool includes 9 questions with 4 criteria: good, fair, poor, and very poor. Having applied the tool to the reviewed studies, a number was assigned to each section of the included studies as follows: 4 for good, 3 for fair, 2 for poor, and 1 for very poor. This produced a score for each study that ranged from 9 to 36. Hawker and colleagues do not suggest any limits for categorizing the sum quality rankings of the article.[28] However, previous studies[29,30] have divided categories into high quality, medium quality and low quality. This stratification of quality has been adapted to the current review and the descriptors for the overall quality were also provided with the ranges in the score: 9–23 points for low quality (C), 24–29 points for medium quality (B), and 30–36 points for high quality (A). The summary of the quality assessment is supplied in appendix B.

Results

Overall, 14,937 articles were retrieved: Medline (n = 600), Embase (n = 6369), International Pharmaceutical Abstracts (n = 618), Scopus (n = 6,266), and Web of Science (n = 1,084). Of these, 5,683 were removed because of repetition and 9,239 were removed for irrelevance. After reviewing the titles, abstracts, and full texts, fifteen publications were identified as being relevant. A further manual search of the reference lists of retrieved articles led to the identification of 4 additional articles. Therefore, the reviewers agreed on a final selection of 19 publications for inclusion. A flow chart of this process is presented in Figure 1.

Nineteen studies (shown in Table 2) evaluated 17 scoring tools for assessing the risk of DRPs and prioritizing the need for pharmaceutical care for patients at the greatest risk of DRPs. All scoring tools were developed by pharmacists and relied on their knowledge and expertise. In other words, all tools were designed by those that would use them.

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163 **Table 2:** A summary of the studies related to the pharmacy risk assessment tools

Reference year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			
Carlson and Phelps (2015)[31]	U.S.	To describe an electronic clinical scoring system to prioritize patient medication monitoring	Descriptive article	NR	NR	In-patients pediatric and adult patients	E	Ph	Enables the identification of patients who could benefit from detailed MedRec	Improves pharmacists' efficiency allowing them to focus their time on high acuity patients	NR	Review article	NR
Cottrell et al. (2013)[32]	U.K.	To develop a tool to identify patients at greatest risk of harm of medication incidents using real time prescribing information from HEPMA	Prospective cohort study	Apr–Oct 2009 Apr–Oct 2011 (12 M)	Fifteen patients, 5 from each risk category (low, medium, and high)	In-patients	E	Ph	Helps to provide safe, effective, and patient centered care.	It has a positive impact on the timely provision of pharmaceutical care to high-risk patients	Does not currently incorporate data from laboratory and other clinical systems; Does not capture co-morbidities and deranged blood results	Small sample size	Validated tool

Covvey et al. (2015)[33]	U.K.	To evaluate a triage tool to prioritize obstetric pharmacy services	Retrospective chart review	June 2014 (1 M)	175	Obstetric patients	P	Ph	Opportunities to improve MedRec, multidisciplinary team coordination and prevention of adverse events	Identifies and prioritizes high-risk obstetric patients for pharmacist review	Measures only obstetric patients. Additional research needed to expand to diverse populations	Small sample size. Capture of pharmacy intervention excluded verbal pharmacists' recommendations	Validated tool

Table 2: Continued

Reference year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			
El hajji et al. (2015)[34]	U.K.	To develop a predictive model to identify patients at high-risk of readmission and post-discharge mortality to prioritize CPS	Retrospective chart review	Oct 2003-Sep 2008	806	In-patients who had received the IMM service at the hospital	NR	Ph	Can be used to identify patients at high risk of readmission, mortality and longer hospital stay	Enables the prioritization of CPS to optimize patient outcomes	It is a complex risk assessment tool as it included score from other algorithms	Small sample size regarding epidemiology investigations	Validated tool

Falconer et al. (2014)[35]	New Zealand	To develop a tool to prioritize in-patients for ADE prevention	Prospective case review	Oct 2010-Sep 2011 (One-Year)	NR	In-patients Adults Patients actively or previously enrolled in CCM program	E	Ph	Facilitate the identification and monitoring of patients at high risk for MEs and ADEs	Enables pharmacists to conduct timely interventions such as MedRec and clinical review; Improves workflow efficiency for CPs and aids medication safety efforts	Laboratory data not linked to the electronic assessment risk tool	Formal validation of the tool to prioritize patients at high, medium, and low risk has not been completed	Non-validated tool
Falconer et al. (2017)[36]	New Zealand	To validate risk assessment tool and determine which of the 25 flags are associated with ADEs	Prospective observational	Sep 2012 to Feb 2013	247	In-patients Adults	Same tool that described in Falconer's paper (2014)					Exclusion of laboratory flags and exclusion of patients admitted during weekends	Validated tool

Table 2: Continued

Reference year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			

Fernandez-Llamazares et al. (2015)[37]	Spain	To design a pharmaceutical care plan for chronic pediatric patients using a risk stratification tool	Prospective study	Apr–Jun 2014	195	In-patients Pediatric patients with chronic conditions	NR	Ph	Stratifies pediatric patients with chronic conditions into distinct risk levels and patients who will benefit from pharmacist intervention	Helps pharmacist to prioritize patients who will benefit from pharmaceutical care intervention	NR	NR	Validated tool
Hickson et al. (2016)[16]	U.K.	To design a pharmaceutical assessment screening (PAST) tool to measure patient acuity and prioritize pharmaceutical care	Quasi-experimental service evaluation	Jan–July 2014	35	In – patients Adults	E	Ph	Ability to rank patient acuity into 3 levels to identify those at greatest risk for developing ADE	Prioritize pharmaceutical care	Scoring varies depending on clinical experience and judgment of individual pharmacist. Has unused sections such as heart, lung, and brain dysfunction	Small sample size	Non-validated tool

Jeon et al. (2017)[38]	U.S.	To develop EHR-based prediction model (C-score) for ranking hospitalized patients based on preventable ADEs	Systematic literature review and survey	Survey (12 days)	37391 ASHP members and 21 preventable ADEs	ASHP members	E	Ph	May improve patient safety by identifying preventable ADEs	Can prioritize patients for pharmacist medication therapy management services	NR	The evaluation of the tool was limited by very low response rate	NR

Table 2: Continued

Reference Year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			
Martinbiancho et al. (2011)[39]	Brazil	To develop a risk screening tool for ADR to guide the allocation of pharmaceutical care	Prospective observational	3 months	1442	In–patients, adults, pediatrics	P	Ph	Detects population at risk of ADR	Helps hospital pharmacists to guide appropriate pharmaceutical care	Uses the number of IV medications as a risk factor which can result in false high score to patients	The score is applied only once to each patient during the hospitalization period	Validated tool

Mondoloni et al. (2016)[40]	France	To develop a medication reconciliation activity for patients at the greatest risk of MEs	Prospective study	2 months	82	In-patients. All patients hospitalized through the emergency room	P	Ph	Helps to identify patients at the greatest risk of medication errors	Enables the pharmacist to act quickly to identify and correct the errors and reduce the pharmacist's workload	NR	Insufficient collection of risk factors by emergency prescribers	NR
Mott et al. (2016)[41]	U.K.	To identify patients at greater need for PhC and the level of pharmacist experience required	Prospective observational study	3 months	245	In-patients. Pediatric patients	P	Ph	Assists in identifying patients in need of a greater level of care	Optimizes pharmaceutical care by directing patients to the most appropriate pharmacist	Developed and validated in a single pediatric hospital limiting its applicability to other patients	NR	NR
Mullan and Jennings (2013)[42]	U.K.	To assess the use of individual features, prioritization, report generation and pharmacist views on the	Survey questionnaire	Feb–Mar 2013	29	All pharmacists covering EP wards	E	Ph	Enables activities that improve patient safety such MedRec, drug interventions and biochemistry	Improves the time utilization by pharmacist and decreases workload; Helps pharmacists to prioritize high-risk patients	The new report is underused, presenting potential problems such as missed doses, and thus requires follow-up studies to identify whether there are any	NR	NR

		EP Web Portal							review	underlying problems		

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171 ***Table 2: Continued***

Reference year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			
Munday and Forrest (2016)[43]	U.K.	To describe a system prioritizing patients based on pharmaceutical care needs (clinical triage and referral system)	Descriptivestudy	NR	NR	In-patients All acute care inpatients	E	Ph	Improves patient prioritization and quality of service, equity of patient care and patient safety	Enables pharmacists to prioritize patients for PhC and improves workflow	The use of triage tool is used together with the professional judgement of the pharmacist may vary outcomes	Review article	Validated tool
Nguyen et al. (2017) [44]	France	To develop a predictive model to identify high-risk patients and the impact on clinical decisions (MEs)	Prospective cohort	March-April 2014	1408	In-patients Adults (≥17 yrs)	E	Ph	Predicts occurrence of MEs to guide intervention for high-risk patients	Improves pharmacist human resource allocation and subsequent patient safety	Tool excluded biological markers, diagnostic categories, and co-morbidities with a high potential for ADRs	Non-harmful MEs were not included	Validated tool

Roten et al. (2010)[10]	Switzerland	To develop and validate a screening tool for DRPs	Prospective, observational, comparative study	Aug–Nov 2007	610	In-patients Adults	E	Ph	Facilitates efficient and rapid screening of patients at risk of DRPs	Allows the clinical pharmacist to prioritize patient medication review and improve their work efficiency	Low specificity due to false positives. The tool does not identify some DRPs such as oral OAC but could be addressed during ward visits	No physician was involved in the classification of clinically relevant interventions	Validated tool

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173 ***Table 2: Continued***

Reference year	Country	Study aim	Study design	Study duration	Sample size	Population group	Tool		Perceived tool benefits		Tool limitations	Study limitations	Tool validity
							Type	Used by	Patient care	Pharmacy services			
Saedder et al. (2016)[45]	Denmark	To develop a screening tool to detect admitted patients at risk of MEs.	Retrospective and Prospective observational study	April 2012 January 2013	302	In-patients Adults (≥18 yrs)	P	Ph	Detects population at risk of MEs	Simple risk-score tool easily automated which facilitate and rapid screening of patient records	The risk-score tool lacked a true reference standard for potential MEs, which is subjective and affected by individual pharmacists' point of view	Small sample size	Validated tool

Safadeh et al. (2012)[46]	U.K.	To design a generic tool for assessing and scoring pharmaceutical needs of in-patients	Prospective cohort	Dec 2010– Jan 2011	68	In-patients Adults	E	Ph	Ensures patients with complex pharmaceutical needs are seen quickly	Allows junior pharmacists to prioritize pharmaceutical needs of patients Pharmacist perceived that this toolkit is easy and quick to use	The tool does not include some pharmaceutical categories such as abuse of drugs and overdoses	Small sample size	Non-validated tool
Saxby et al. (2016)[47]	U.K.	To determine pharmacists' views on PAST to assess PAL and factors for assigning PAL level	Survey questionnaire	NR	32	Pharmacists	Same tool as described in Hickson's paper		Ability to rank patient acuity into 3 levels to identify those at greatest risk for developing ADE	Pharmacists are comfortable using PAST for assessing PAL and monitoring pharmaceutical care	Requires careful design and appropriate training for effective use	Professional level varies in the assignment of PAL	Non-validated tool

Notes: **NR:** Not reported; **E**: Electronic; **P**: Paper; **Ph:** Pharmacist; PhC: Pharmaceutical care; **HEPMA:** Hospital Electronic Prescribing and Medicines Administration; **MedRec:** Medicine reconciliation; **M:** Month, **CPS:** Clinical pharmacy service; **IMM:** Integrated medicines management; **CCM:** Chronic care management; **MEs:** Medication error; **ADR:** Adverse drug reaction; **CP**: Clinical pharmacist; **ART:** Assessment of risk tool; **PAST:** Pharmaceutical Assessment Screening Tool; **EHR:** Electronic health record; **C-score:** Complexity score; **ASHP:** The American Society of Health System Pharmacists; **EP:** Electronic prescribing; **DRP:** Drug-related problem; **OAC:** Oral anticoagulant; **CPOE**: Computerized physician order entry; **PAL:** Patient acuity level.

Regarding quality assessment, 10 studies were identified as high quality, 4 as medium quality and 5 as low quality. Despite some being of lower quality than others, all studies were relevant to the research and were therefore included in this review. None of the reviewed papers were of very poor quality. The number of scoring tools was lower than the number of studies because the pharmaceutical assessment screening tool (PAST)[16] and the assessment risk tool (ART)[35] were each applied in two different studies.[36,47] Where PAST, a tool for measuring patient acuity and prioritizing pharmaceutical care, was designed in an initial study,[16] a subsequent study[47] attempted to establish pharmacists' attitudes toward the tool. Similarly, an initial study[35] described the development of the ART for prioritizing in-patients for the prevention of ADEs, and a follow-up as followed by study[36] which validated the same tool. Most (14/17) of the tools were published in the last 5 years, revealing an increased interest in the development of risk assessment tools globally. The studies were conducted in diverse regions of the world. More studies regarding the development of priority tools were conducted in Europe (n = 14; 73%)[10,16,32–34,37,40–47] with the U.K. leading with 9 (47%) studies.[16,32–34,41–43,46,47] Table 2 shows the countries which have developed and published a tool.

The studies adopted various research designs. Most (n = 11; 58%) were prospective observational studies, either single center or multi-center.[10,32,35–37,39–41,44–46] The remaining studies were retrospective observational studies,[33,34] descriptive,[31,43] systematic review/ survey,[38] quasi-experimental study,[16] and survey.[42,47]

The studies varied because they addressed diverse aims. Most studies (79%) assessed distinct risk screening tools to assess their ability to identify patients at greatest risk of ADRs, ADEs, or MEs and to guide appropriate pharmaceutical care.[10,16,32–41,44–46] Two studies assessed their tools, and pharmacists' views of them.[42,47] Two other studies provided a description of an electronic clinical scoring system to prioritize patients based on pharmaceutical care needs.[31,43] One study[41] investigated a tool for assigning patients with a higher need of pharmaceutical care to the appropriate pharmacist.

The studies also varied in that they target diverse patient populations applicable to their settings including adult patients (≥ 18 years),[10,16,35,36,44–46] pediatric patients (< 18 years),[37,41] and obstetric patients.[33] Furthermore, some studies targeted pharmacists and measured their opinions of existing tools.[42,46,47] Ten tools were developed electronically,[10,16,31,32,35,38,42–44,46] 5 in paper form,[33,39–41,45] and 2 studies did not state the tool format.[34,37] Some of the electronic tools used electronic algorithms[10,44] and some were simply stored electronically.[16,31,32,35,38,42,43,46]

Thematic analysis

Three overarching themes were identified. The positive impact of the risk assessment tools on patient care, the positive impact of the risk assessment tools on the delivery of pharmacy services, and limitations of risk assessment tools. During the thematic analysis of the tool benefits, 2 subthemes for patient care and 4 subthemes for pharmaceutical care were identified (Fig. 2).

The positive impact of the risk assessment tools on patient care

The first overarching theme during the thematic analysis was identified as the positive impact of the risk assessment tools on patient care. There was a consensus among the studies that the various assessed risk-scoring tools are beneficial in identifying patients at higher risk of DRPs and consequently in guiding pharmaceutical care. They conveyed several benefits to patients and pharmacists. For patients, 2 subthemes were found across the 19 studies. The first subtheme was concerned with identifying high-risk patients to improve the quality of pharmacy services and improve patient safety. For instance, one tool was capable of ranking patient acuity into 3 levels according to the potential risk of developing ADEs.[16] Another study[45] showed that their tool could identify patients at risk of developing MEs. Two studies[37,41] were able to stratify pediatric patients into diverse risk levels, which could be used to prioritize those patients who would benefit more from pharmacists' interventions. One study[34] emphasized the ability of their tool to identify patients at high risk of readmission, longer hospital stay, and post discharge mortality.

The second subtheme was concerned with identifying high-risk patients who could benefit from medication reconciliation. Medication reconciliation is a formal process of ensuring patients' prescribed medication matches with what they are actually taking.[48] One study[33] examined opportunities to improve medication reconciliation, multidisciplinary team coordination, and the prevention of adverse events. Another study[31] described an electronic clinical scoring system that was able to identify patients who could benefit from detailed medication reconciliations.

The impact of the risk assessment tools on the delivery of pharmacy services

Regarding benefits of the tools for pharmacists and hospital managers, the impact on the provision of pharmacy services was identified as the second overarching theme during the thematic analysis. Four subthemes were identified. The first subtheme was the prioritization

of pharmaceutical care. Nine studies identified the tools as beneficial in prioritizing, guiding and monitoring pharmaceutical care to conduct interventions, such as medication review, medication reconciliation, clinical review, and medication therapy management services.[10,16,33,35–39,47]

The second subtheme related to pharmacists' effective time management and workload efficiency. Each study had a distinct approach with some focusing on the improvement of work flow or workload efficiency,[31,35,36,40,42,43] others focusing on the timely provision of pharmaceutical care,[31,32,40] and still others on the rapid screening of patient records.[45]

The third subtheme was related to optimizing human resources and the allocation of pharmacists to patients, which was based on patient complexity and the expertise of pharmacists. One study[44] concluded that patient-specific allocation of clinical pharmacy services could be more efficient at the time of patients' hospital admission. Another study[41] focused on optimizing pharmaceutical care by directing the care of pediatric patients to the most knowledgeable and experienced pharmacist.

The fourth subtheme dealt with the attitudes of pharmacists to the tools. The tool described in two studies[42,46] was perceived by pharmacists as easy and quick to use and pharmacists were comfortable using the PAST for assessing patient acuity level.[47] It also allowed junior pharmacists to focus on and prioritize the pharmaceutical needs of patients.[46] Notably, this was the only study referring to the perceptions of junior pharmacists regarding the tool.

Limitations of risk assessment tools

The limitations of risk-scoring tools were identified as the third overarching theme. This theme is related to the design of tools and included the lack of, or incompleteness of, data collection, which was described commonly as a tool limitation. In 2 studies that used the same tool, laboratory data were not linked to the risk assessment tool and excluded patients

who were admitted during weekends.[35,36] Other tools did not identify some DRPs,[10] or excluded drug overdose,[46] biological markers,[44] diagnostic categories,[44] comorbidity, deranged blood results,[32,44] and laboratory data.[32]

Some limitations were also associated with scoring differences. The authors of 3 studies described that the tools had variations in scoring, depending on clinical experience and judgment of individual pharmacists.[16,43,45] Two other studies required careful tool design and pharmacists to be trained to use the tool more effectively.[16,47]

Tool validity

Regarding validity, 10 out of 17 tools were validated with 2 studies explicitly stating the tools were not validated. However, 5 studies did not state if the tools were validated. Validity was measured by obtaining risk indicators from the literature, and assessing them for inter-observer agreement and agreement with other indicators.[39] One tool was validated by using an expert group of 3 clinical pharmacists delivering obstetric services, as well as formal input from several academic collaborators.[33]

In one study,[10] the use of the screening tool was compared across 4 clinical pharmacists. The tool was developed in a pre-existing population and validated in a pilot prospective study.[45] In another study,[37] a pre-test tool was developed and used in 195 patients from 7 hospitals. In the description of an electronic tool, one study[43] stated that the tool was piloted for triage and referral. In another study,[44] the data about MEs was fitted and internally validated using a multivariate logistic model to predict occurrence.

In the ART, 38 flags were used to in the determination of patient prioritisation.[35] A subsequent study of the tool,[36] identified that 25 flags of the original 38 to be significantly associated with the risk of unintentional MEs. To improve validity, another study[34] divided a sample of patients (n = 806) into a development sample (n = 605) and a validation sample (n

= 201) to create risk-predictive algorithms that would aid in developing a predictive model for identifying patients at high risk of readmission and post-discharge mortality. In another study, 5 patients were assigned to each risk group which were reviewed with the score being assigned based on group's validation of pharmaceutical risk.[32]

Risk factors included in the tools

The risk factors that each tool incorporated to determine acuity were placed into 2 categories: drug related (7 risk factors) and patient related (8 risk factors). Two additional categories included other risk factors, which did not fit into either category. The most common risk factors (see Table 3) identified were as follows in descending order of prevalence: high-risk medication (15/17 tools, 88%), drugs requiring monitoring (15/17 tools, 88%), polypharmacy (13/17 tools, 76.5%), use of total parenteral nutrition/nasogastric tube (3/17 tools, 17.6%), high-cost medication, and number of intravenous and unlicensed medication (1 tool each, 6%). Several definitions of polypharmacy exist, ranging from the prescription of 3 to 6 medications or in some cases more. Notably, some studies failed to include the criteria for defining high-risk medication.[31,32,37,41,42,46] Five tools included various other factors that were not frequently used across all tools, such as cytochrome P450 inducers and inhibitors, blood substitutes, drug induced hemorrhage, and acute kidney injury. They can be found in the "Other" column. The patient related category included other risk factors, which are listed in descending order of prevalence: age (13/17 tools, 76.5%), renal impairment (9/17 tools, 53%), comorbidity (9/17 tools, 53%), hepatic impairment (5/17 tools, 29%), reason/time/type of admission (5/17 tools, 29%), readmission (3/17 tools, 18%), allergies (3/17 tools, 18%), and length of stay (2/17 tools, 12%). Other studies mentioned other factors, such as human immunodeficiency virus, cystic fibrosis, Parkinson's disease, depression, and other factors (Table 3).

318

319 **Table 3**: A summary of the risk factors

	Drug related											Patient related					
Reference/ year	**Polypharmacy**	**Number of IV medicine**	**High-risk medications**	**High cost**	**Use of TPN/NGT**	**Need monitoring**	**Unlicensed**	**Other**	**Age**	**Renal**	**Liver**	**Co morbid**	**Allergy**	**Readmission**	**Reason, time, and type of admission**	**Length of stay**	**Other**
Carlson and Phelps (2015)[31]	_	_	+	_	+	+	_	_	+	+	_	_	_	_	_	_	_
Cottrell et al. (2013)[32]	+	_	+	_	_	+	+	_	_	_	_	_	+	_	_	_	_
Covvey et al. (2015)[33]	+	_	+	_	_	+	_	_	+	+	+	+	+	_	_	_	DM, depression, schizophrenia, asthma, HTN, HIV, Crohn's disease
Elhajji et al (2014)[34]	+	_	+	_	_	+	_	_	+	_	_	+	_	+	_	+	_
Falconer et al. (2014)[35]	+	_	+	_	_	+	_	_	+	+	_	+	_	+	_	_	DM, COPD, CHF, CVD, Poor medication adherence
Falconer	Same tool that described in Falconer's paper (2014)																

et al. (2017)[36]

320

321 ***Table 3: Continued***

	Drug related								Patient related								
Reference/ year	**Polypharmacy**	**Number of IV medicine**	**High-risk medications**	**High cost**	**Use of TPN/NGT**	**Need monitoring**	**Unlicensed**	**Other**	**Age**	**Renal**	**Liver**	**Co morbid**	**Allergy**	**Readmission**	**Reason, time, and type of admission**	**Length of stay**	**Other**
Fernandez et al. (2015)[37]	+	–	+	–	–	–	–	–	+	–	–	+	–	–	+	–	Obesity, malnutrition, and cognitive/social problems
Hickson et al. (2016)[16]	–	–	+	+	–	+	–	–	–	+	+	+	–	–	–	–	HIV, CF, and Parkinson's Disease
Jeon et al. (2017)[38]	–	–	+	–	–	+	–	Drug-induced hemorrhage, acute kidney injury, severe electrolyte imbalances, hepatic failure, blood dyscrasia, seizures, and							NR		

									uncontrolled hospital acquired infection									
Martinbiancho et al. (2011)[39]	+	+	+	_	+	+	_	_	+	+	+	+	_	_	-	-	Cardiac problems, pulmonary problems, and immunosuppression	

322

323 ***Table 3: Continued***

	Drug related								Patient related									
Reference/ year	**Polypharmacy**	**Number of IV medicine**	**High-risk medications**	**High cost**	**Use of TPN/NGT**	**Need monitoring**	**Unlicensed**	**Other**	**Age**	**Renal**	**Liver**	**Co morbid**	**Allergy**	**Readmission**	**Reason, time, and type of admission**	**Length of stay**	**Other**	
Mondoloni et al. (2016)[40]	+	_	+	_	_	+	_	_	+	_	_	+	_	_	_	_	HTN, HF, diabetes, cancer, and memory disorder	
Mott et al. (2016)[41]						NR			+	_	_	+	+	_	+	_	Early warning score and medicines reconciliation	

Mullan et al. (2013)[42]	+	_	+	_	_	+	_	Drug interaction. Pharmaceutical biochemistry alert such as heparin induced thrombocytopenia	_	_	_	_	_	_	+	+		_
Munday and Forrest (2016)[43]	+	_	+	_	_	+	_	Significant drug interaction. IV antibiotics	+	+	+	_	_	_	+	_	Patient has undergone surgery/procedure. Patient with swallowing difficulties/oral route not available.	
Nguyen et al. (2017) [44]	+	_	+	_	+	+	_	Blood substitutes	+	_	_	_	_	+	+	_		_

Table 3: Continued

	Drug related								Patient related									
Reference/ Year	**Polypharmacy**	**Number of IV medicine**	**High-risk medications**	**High cost**	**Use of TPN/NGT**	**Need monitoring**	**Unlicensed**	**Other**	**Age**	**Renal**	**Liver**	**Co morbid**	**Allergy**	**Readmission**	**Reason, time, and type of admission**	**Length of stay**	**Other**	

Roten et al. (2010)[10]	+	_	+	_	_	+	_	Cytochrome P450 inducers and inhibitors, IV acetaminophen, anti- infectives > 3 days and patients on digoxin with low serum potassium	+	+	_	_	_	_	_	_	_
Saedder et al. (2016)[45]	+	_	+	_	_	+	_	_	+	+	_	+	_	_	_	_	_
Safadeh et al (2012)[46]	+	_	_	_	_	+	_	Drug interaction, drug specific issue, and administration issue	+	+	+	_	_	_	_	_	_
Saxby et al. (2016)[47]	Same tool that described in Hickson's paper (2016)																		
Total of studies	13	1	15	1	3	15	1	_	13	9	5	9	3	3	5	2	_		

+: Risk factors were included in the study; -: Risk factors were not included in the study; IV: Intravenous infusion; TPN: Total parenteral nutrition; NGT: Nasogastric tube; DM: Diabetes mellitus; HTN: Hypertension; HIV: Human immunodeficiency virus; COPD: Chronic obstructive pulmonary disease; CHF: Congestive heart failure; CVD: Cerebrovascular disease; CF: Cystic fibrosis; HF: Heart failure; NR: Not reported.

High-risk drug classes

Twelve drug classes were identified in the 19 studies. The summary of drug classes is supplied in appendix C. Some classes of drugs were considered more important than others in the risk assessment tools and are listed in the order of frequency: anticoagulants (14/17 tools, 82%), cardiovascular medication (12/17 tools, 70.5%), antiepileptics (12/17 tools, 70.5%), antimicrobial medication (12/17 tools, 70.5%), chemotherapy (10/17 tools, 59%), aminoglycosides (a subgroup of antimicrobials; 10/17 tools, 59%), immunosuppressants (9/17 tools, 53%), hypoglycemic/insulin (9/17 tools, 53%), opiates (9/17 tools, 53%), antidepressants (7/17 tools, 41%), anti-inflammatories/NSAIDs (5/17 tools, 29%), and corticosteroids (3/17 tools, 18%). Other studies mentioned other medications, such as potassium chloride (IV), eye drops, theophylline, aminophylline, and anti-retrovirals.

Discussion

The present study is the first review to identify and describe the tools that have been designed and are currently used by clinical pharmacy services to assess patient acuity and complexity. The included studies provide a solid foundation for the reader to enhance their understanding of existing tools that may aid detection of high acuity patients for early and targeted pharmacist interventions. This study focuses exclusively on pharmacist tools and does not reflect on other healthcare professionals, which are outside of the scope of this study.

This review revealed a rising interest in the development of risk assessment tools for DRPs to categorize patients as high-risk and to prioritize pharmaceutical care. The UK seems to have placed a greater emphasis on the development of such tools with other countries following suit. It could be postulated that this interest stems from the unique nature of the UK's National Health Service, which is free at the point of use and funded solely via general Government taxation.[49] Rising numbers of patients and funding pressures within this service have heightened over recent years, and there is a drive to maximize efficiency across the NHS.[15,19,20,22] Thus, a possible explanation is that this situation increases the pressure on NHS pharmacy departments to prioritize which patients need direct pharmaceutical care.

Most tools reviewed in the present study were developed for adults aged older than 17 years. In 2 studies,[37,41] the emphasis was on pediatric patients. No tools have been found that focused on elderly patients within the hospital setting; however, such patients were included in the studies of the general adult population. This is interesting since elderly patients are more likely to have multiple morbidities and associated complex pharmacotherapy, which puts them at risk of adverse outcomes.[39]

This review highlighted the variation in the complexity and use of algorithms. It also demonstrated that most tools have been designed in an electronic format to ease the screening process and to reduce the amount of time spent by pharmacists on retrieving patient records, as well as reducing the amount of paperwork.[31,42,46] However, most of the studies that were reviewed failed to explain how the tools operate.

The tools include many risk factors. The most prevalent risk factors are high-risk medications—medications requiring monitoring, age, and polypharmacy. Regarding high-risk medications, there was no consistent definition of "high risk" in the reviewed studies. High-risk medication has been defined as harmful to patients[15]; therefore, awareness of their harm to patients, can potentially decrease the hospitalization period, life-threatening conditions, and death by almost 50%.[50] The four most commonly named drug classes in all the reviewed studies were: anticoagulants, antimicrobials, cardiovascular, and antiepileptic drugs. This finding correlates with other studies that have reported similar drug classes to be associated with hospital setting problems.[50,51]

Furthermore, this review found polypharmacy is commonly considered a risk factor for requiring pharmaceutical care. This finding was supported by several studies that concluded that polypharmacy can lead to negative health outcomes and frequent hospitalization by influencing DRPs.[52–55] Polypharmacy is particularly prevalent among the elderly population who are more likely to have multiple conditions.[10]

Hospital length of stay is also considered a key indicator of resource usage in hospitals.[56] Length of stay and hospital costs are often correlated.[57] Only 2 reviewed tools included length of stay as a risk factor. The reason for this was not stated in the

388 other studies. One of the reasons could be some tools were used at the beginning of
389 hospital admission.

390 The tools were reported to have clear benefits regarding patient care and pharmacy
391 services delivery. However, some of these benefits are the perceptions of those using
392 and implementing the tools, and were not necessarily confirmed by robust data to
393 verify these perceptions. The tools on the whole aim to improve pharmacists'
394 workload and help them work more efficiently. This goal seems to have been
395 achieved in other healthcare settings. For instance, decision makers can already use
396 the acuity-scoring tools to assist in assigning the appropriately experienced and
397 knowledgeable nurse to the right patient.[58,59] This ensures a more consistent quality of
398 care, decreases mortality rates, improves outcomes, and shortens hospital stays.[58] The
399 tools have reportedly many benefits for both the pharmacy team and patients;
400 inevitably, however, in addition to the tools, clinical experience still plays a critical
401 role in pharmacists' decisions regarding outcomes and scoring of patients.

402 Overall, only one publication focused on an assessment tool for patients, which
403 assisted in directing the right pharmacist to the right patient in the pediatric
404 department; however, there was insufficient detail provided in this study.[41] Therefore,
405 more research is needed to explore how tools are used to allocate the most
406 appropriately experienced pharmacist to individual patients in the general inpatient
407 population. Only 3 studies[42,46,47] explored pharmacists' views of the tools and further
408 work is necessary to gain a more complete picture of the impact of tools on the
409 individual pharmacist and their own acquisition of knowledge and skills.

410 The safety of patients has been significantly improved by providing clinical
411 pharmacist services among diverse hospital services.[12] Clinical pharmacy services
412 have a positive impact on patients' outcomes by decreasing MEs, ADEs, and

ADRs.[12,51,60] Risk assessment tools could be of benefit to patients as such tools provide early indicators to detect MEs. Interestingly, the impact of tools on patients and on MEs and ADEs has not been demonstrated in any of the studies. Hence, there is a need for more research that investigates the impact of the tools on patient care quality and patient safety.

When we assessed the quality of the studies within the review, some were ranked as low quality but still included. These low ranking studies were abstracts to conferences presenting the assessment tools developed within their hospitals. The papers connected to the abstracts had not been published as full academic papers at the time of the review. The process of academic publication is time-consuming and requires research skills which may form a barrier to the publication of studies undertaken by practising pharmacists who have competing pressures. A recent study of assessment tools used in UK hospital pharmacies indicated that there are a number of tools that have been developed but have not been presented at a congress or meeting.[61] This leads us to believe that the number of tools is likely to be much higher than those that are formally disseminated through conferences and academic publications.

The findings of this review have several implications for pharmacy practice. Those pharmacists who work in clinical practice and are considering adopting or developing their own prioritization tool can take some reassurance that current published tools appear to achieve their aim of successfully targeting clinical pharmacy services to where they are needed most. The tools presented in this review could be adapted or further developed to suit differing clinical and organizational contexts. Lessons that have been learned from exploring the limitations of existing tools include the need for thorough training in the application of tools and extensive consideration of the

inclusion of relevant risk factors to ensure accuracy of detecting high acuity patients. Going forward tool implementation should be monitored, validated and where possible its impact measured to allow for comparison across tools.

Limitations

Only studies written in English were included in this review, which may mean that noteworthy studies published in other languages were overlooked. The literature search, abstract and full-text screening and quality assessment were performed by only one of the authors (MA). It was difficult to gain fair results when applying Hawker's quality assessment tool, since some abstracts lack the sufficient detail to meet quality assessment criteria. Despite this, it was important to include abstracts if they provided sufficient information about a prioritization tool, due to the limited published literature in this area.

Limitations of the included studies are that the tools were not described in full detail; for example, there is a lack of description about what constitutes a high-risk medication. Overall, the published assessment tools are very heterogeneous and differ in aim, structure, content, targeted patient groups, and the extent of validation. As a result comparison across studies and generalizability of the review findings are limited.

Conclusion

This review is the first to provide a summary of currently published tools that will be of use to researchers and pharmacy managers interested in current approaches to identifying those patients are at the greatest risk from DRPs. It is clear that there has

been growing interest in the development of risk assessment tools in recent years. Seventeen published papers have described screening tools designed and used in clinical pharmacy services for the assessment of patients to identify high acuity patients and guide pharmaceutical care. Overall, published assessment tools are heterogeneous, differing in structure, content, targeted patient group, setting, selected outcomes, and extent of validation.

Despite this authors were unanimous in that these tools are beneficial in identifying patients perceived to be at higher risk of DRPs and consequently in guiding the provision of pharmaceutical care.

Current published studies fail to provide a measurable impact of the tools on patients and their ability to prevent actual harm from medication use. Future studies should attempt to measure patient outcomes and apply similar methods to facilitate comparison across different tools. There is clearly no “gold standard,” in terms of pharmacy specific acuity tools and more work is needed to ensure a consistent, high-quality approach to prioritization of services.

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688 **Figure captions**

689 **Figure 1:** Flow diagram of articles included/excluded in the systematic literature review

690 **Figure 2:** The themes and their subthemes of the tool benefits and limitations

691

692 **Supplementary files: Appendices**

693 **Appendix A: Search strategy**

694 **Appendix A1: Search strategy for Medline:**

#	Searches	Results
1	priorit*.mp. [mp = title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, and synonyms]	86838
2	triage*.mp.	17228
3	acuity.mp.	90954
4	complex*.mp.	1273626
5	1 or 2 or 3 or 4	1458036
6	tool*.mp.	486875
7	scor*.mp.	697844
8	screen*.mp.	617050
9	criteria.mp.	438374
10	scale.mp.	477813
11	classif*.mp.	469517
12	assess*.mp.	2477446
13	measure*.mp.	2663537
14	instrument*.mp.	235132
15	clinical assess* tool*.mp.	300
16	stratif*.mp.	124843
17	software.mp.	176740
18	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17	6245139
19	hospital*.mp.	1275983
20	secondary care.mp.	4532
21	19 or 20	1278712

22	pharmaceutical care.mp.	1657
23	pharmacy.mp.	51434
24	pharmacist*.mp. protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	26710
25	pharmac* service*.mp.	26496
26	hospital pharmac*.mp.	3461
27	clinical pharmac*.mp.	13611
28	clinical pharmac* service*.mp.	650
29	pharmaceutical.mp.	179014
30	22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	233049
31	5 and 18 and 21 and 30	719
32	31	719
33	limit 32 to (English language and year = “1990–current”)	600

695

696 **Appendix A2: Search strategy for Embase:**

#	Searches	Results
1	priorit*.mp. [mp = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, and floating subheading word]	9168508
2	triage*.mp.	22471
3	acuity.mp.	130033
4	complex*.mp.	1693722
5	1 or 2 or 3 or 4	10273035
6	tool*.mp.	765972
7	scor*.mp.	1230975
8	screen*.mp.	1095141
9	criteria.mp.	739223
10	scale.mp.	891130
11	classif*.mp.	1002668
12	assess*.mp.	4118394
13	measure*.mp.	3693220
14	instrument*.mp.	576368
15	clinical assess* tool*.mp.	21453
16	stratif*.mp.	219590
17	software.mp.	236855
18	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17	9850574
19	hospital*.mp.	2113138
20	secondary care.mp.	9034
21	19 or 20	2117652
22	pharmaceutical care.mp.	18711
23	pharmacy.mp.	114623
24	pharmacist*.mp.	85677
25	pharmac* service*.mp.	6732

26	hospital pharmac*.mp.	16937
27	clinical pharmac*.mp.	44609
28	clinical pharmac* service*.mp.	1296
29	pharmaceutical.mp.	181080
30	22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	346837
31	5 and 18 and 21 and 30	6735
32	31	6735
33	limit 32 to (English language and year = “1990–current”)	6369

697

698 **Appendix A3: Search strategy for International Pharmaceutical Abstracts:**

#	Searches	Results
1	priorit*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	1885
2	triage*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	233
3	acuity.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	454
4	complex*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	25420
5	1 or 2 or 3 or 4	27826
6	tool*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	10336
7	scor*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	15498
8	screen*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	12510
9	criteria.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	12441
10	scale.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	10954
11	classif*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	9518
12	assess*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	63762
13	measure*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	54279
14	instrument*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	3625

15	clinical assess* tool*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	4
16	stratif*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	2473
17	software.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	3687
18	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17	145434
19	hospital*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	54586
20	secondary care.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	166
21	19 or 20	54683
22	pharmaceutical care.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	6664
23	pharmacy.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	64385
24	pharmacist*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	51415
25	pharmac* service*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	19273
26	hospital pharmac*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	15956
27	clinical pharmac*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	11158
28	clinical pharmac* service*.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	2771
29	pharmaceutical.mp. [mp = title, subject heading word, registry word, abstract, and trade name/generic name]	50974
30	22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	114055

31	5 and 18 and 21 and 30	687
32	31	687
33	limit 32 to (English language and year = “1990–current”)	618

699

700 **Appendix A4: Search strategy for Scopus:**

#	Searches	Results
1	TITLE-ABS-KEY (priorit* OR triage* OR acuity OR complex*)	12430249
2	TITLE-ABS-KEY (tool* OR scor* OR screen* OR criteria OR scale OR classif* OR assess* OR measure* OR instrument* OR {clinical assess* tool*} OR stratif* OR software)	18978666
3	TITLE-ABS-KEY (hospital* OR secondary care)	777177
4	TITLE-ABS-KEY ({pharmaceutical care} OR pharmacy OR {pharmac* service*} OR {hospital pharmac*} OR {clinical pharmac*} OR {clinical pharmac* service*} OR pharmacist* OR pharmaceutical)	37178
5	1 AND 2 AND 3 AND 4	6760
6	5 AND PUB YEAR > 1989 AND (LIMIT-TO (LANGUAGE, "English")	6266

701

Appendix A5: Search strategy for Web of Science:

#	Searches	Results
1	priorit* OR triage* OR acuity OR complex*	3409659
2	tool* OR scor* OR screen* OR criteria OR scale OR classif* OR assess* OR measure* OR instrument* OR clinical assess* tool* OR stratif* OR software	12369905
3	hospital* OR secondary care)	8866054
4	pharmaceutical care OR pharmacy OR pharmac* service* OR hospital pharmac* OR clinical pharmac* OR clinical pharmac* service* OR pharmacist* OR pharmaceutical	333277
5	1 AND 2 AND 3 AND 4	1188
6	limit 5 to (English language and year = "1990–current")	1084

704 **Appendix B:** Quality assessment of included studies (Hawker's quality assessment tool[28])

Reference year	Abstract and title				Introduction and aims				Method and data				Sampling				Data analysis				Ethics and bias				Findings/results				Generalizability				Implications/usefulness				Sum score	Overall quality
	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor	Good	Fair	Poor	Very Poor		
Carlson and Phelps (2015)[27]				1		3				2					1				2				2				2				2				4				**19**	**C***
Cottrell et al. (2013)[28]			2			3				3				2					2				3				3				2				4				**24**	**B***
Covvey et al. (2015)[29]	4				4					3				2			4					3			4					2				4				**30**	**A***
Elhajji et al. (2014)[30]	4				4					3				3			4					3			4					3				4				**32**	**A***
Falconer et al. (2014)[31]	4				4					3				2				3				3			4					3				4				**30**	**A***
Falconer et al. (2017)[32]	4				4					3				3			4					3			4					3				4				**32**	**A***
Fernandez-Llamazares et al. (2015)[33]	4						2				2				2				2				1			2					2					3			**19**	**C***
Hickson et al. (2016)[14]	4				4					3				2			4					3			4					2				4				**30**	**A***
Jeon et al. (2017)[34]	4				4				4					3				3				3			4					3				4				**32**	**A***
Martinbiancho et al. (2011)[35]		3				3				3				3			4						1			3					3				4				**27**	**B***

Mondoloni et al. (2016)[36]	3			2		3			2		2		2		2		2		3		**21**	**C***
Mott et al. (2016)[37]	4			2		2			2		2		2		2		2		3		**21**	**C***
Mullan et al. (2013)[38]	4			3		3			3		2		3		3		2		4		**27**	**B***
Munday and Forrest (2016)[39]		2		3		2			1		2		2		2		2		3		**19**	**C***
Nguyen et al. (2017)[40]	4			4		4			4		4		3		4		3		4		**34**	**A***
Roten et al. (2010)[9]	4			4		3			4		4		3		3		3		4		**32**	**A***
Saedder et al. (2016)[41]	4			4		4			3		4		2		3		3		4		**31**	**A***
Safadeh et al. (2012)[42]	4			3		3			2		2		2		3		2		4		**25**	**B***
Saxby et al. (2016)[43]	4			4		3			3		4		3		4		3		4		**32**	**A***

*High quality (A), 30–36 points

*Medium quality (B), 24–29 points

*Low quality (C), 9–23 points.

Appendix C: A summary of high-risk drug classes included in tools

Reference/ year	Classes of drugs												
	Anticoagulants	**Antimicrobial**	**Cardiovascular**	**Chemotherapy**	**Opiates**	**Hypoglycemic/Insulin**	**Antiepileptics**	**Aminoglycosides**	**Corticosteroids**	**Anti-inflammatory NSAIDs**	**Immunosuppressants**	**Antidepressant**	**Other**
Carlson and Phelps (2015)[31]	+	+	+	+	_	_	+	+	_	_	+	+	Lithium
Cottrell et al. (2013)[32]	+	+	_	+	_	_	+	_	_	_	+	_	_
Covvey et al. (2015)[33]	+	+	+	_	+	+	+	+	+	+	+	+	Lithium Anti-retrovirals
El hajji et al. (2014)[34]	+	_	+	+	+	_	+	_	+	+	_	+	_
Falconer et al. (2014)[35]	+	+	+	_	+	+	+	+	_	_	_	_	_
Falconer et al. (2017)[36]	Same tool that described in Falconer's paper (2014)												
Fernandez et al. (2015)[37]	NR												

Hickson et al. (2016) [16]	+	+	+	+	+	+	+	+	_	_	+	_	Theophylline Aminophylline Lithium Anti-retrovirals

712

713 ***Appendix C: Continued***

	Classes of drugs												
Reference/ year	**Anticoagulants**	**Antimicrobial**	**Cardiovascular**	**Chemotherapy**	**Opiates**	**Hypoglycemic/Insulin**	**Antiepileptics**	**Aminoglycosides**	**Corticosteroids**	**Anti-inflammatory NSAIDs**	**Immunosuppressants**	**Antidepressant**	**Other**
Jeon et al. (2017)[38]	+	+	+	_	+	+	_	+	_	_	+	_	_
Martinbiancho et al. (2011)[39]	+	+	+	+	+	+	+	+	+	_	+	_	Potassium chloride (IV)
Mondoloni et al. (2016)[40]	+	_	+	+	_	+	+	_	_	_	_	-	Eye drops
Mott et al. (2016)[41]	NR												

Mullan et al. (2013)[42]	+	+	+	_	+	+	+	+	_	_	_	_	_
Munday and Forrest (2016)[43]	+	+	_	+	_	_	+	+	_	+	+	+	_
Nguyen et al. (2017)[44]	+	+	+	+	+	+	_	+	_	+	_	+	Lithium
Roten et al. (2010)[10]	+	+	+	+	_	_	+	+	_	_	+	+	_
Saedder et al. (2016)[45]	+	+	+	+	+	+	+	_	_	+	+	+	Lithium
Safadeh et al. (2012)[46]	NR												
Saxby et al. (2016)[47]	Same tool that described in Hickson's paper (2014)												
Total of studies	14	12	12	10	9	9	12	10	3	5	9	7	_

+: Drug classes were included in the study; -: Drug classes were not included in the study; NR: Not reported.