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Evidence Check

Implementing system-wide risk stratification approaches

An **Evidence Check** rapid review brokered by the Sax Institute for the
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This report was prepared by:

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Implementing system-wide risk stratification approaches: a review of critical success and failure factors

This report was prepared by James Gillespie, Carmen Huckel Schneider, Andrew Wilson, Adam Elshaug

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Contents

List of abbreviations

ACG	Adjusted Clinical Group
ACI	Agency for Clinical Innovation
ADACP	American Diabetes Association Clinical Practice
aOR	Adjusted odds ratio
ASSEHS	Activation of Stratification Strategies and results of the interventions on frail patients of Healthcare Services
CARS	Community Assessment Risk Screen
CHD	Coronary Heart Disease
CHP	Community Health Partnership (Scotland)
CI	Confidence interval
CM	Care Management
CMO	Care Management Organisation (US)
CPRM	Combined Predictive Risk Model
CSSG	Case Smart Suite German
DPoRT	Diabetes Population Risk Tool
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
GP	General Practitioner
HCC	Hierarchical Condition Category
ICDMP	Indiana Chronic Disease Management Program
FINDRISC	Finnish Diabetes Risk Score
FRS	Framingham Risk Score
JADE	Joint Asia Diabetes Evaluation Risk Engine
JHUACG	Johns Hopkins University Adjusted Clinical Groups
KPSC	Kaiser Permanente Southern California
LACE	Length of Stay, Acuity of Admission, Comorbidities, Emergency Department Visits
LVH	Left Ventricular Hypertrophy
NHMRC	National Health and Medical Research Council
NHS	National Health Service
PARR	Patients at Risk of Readmission
PC	Primary Care
PCT	Primary Care Trust (UK)
PCP	Primary Care Physician
Pra	Probability of Repeated Admission
RAMP-DM	Risk Assessment and Management Program for Patients with Diabetes Mellitus
SPARRA	Scottish Patients at Risk of Readmission and Admission

1 Executive summary

This rapid review has been commissioned by the Agency for Clinical Innovation (ACI) and the Sax Institute to inform decisions on the potential implementation of risk stratification approaches in NSW.

The focus of this review (which will complement others) is the implementation of risk stratification tools. In this report, the term risk stratification tool is used to refer to all models, tools and systems that use algorithms to predict future risk of mortality, morbidity or health service usage (including hospitalisation, rehospitalisation and pre-hospital service usage) for a particular defined population.

Papers that studied or described the adaption of a standard risk stratification tool for a new context or the implementation of a tool were included in the review. Studies that examined the development or validation of tools, or the testing of their predictive accuracy were excluded.

We undertook a two-pronged approach to search for literature. First, a systematic search was conducted in Medline, Embase, Scopus, the Cochrane Library and CINAHL databases. Second, focused searches were conducted in peer-reviewed and grey literature for specific risk stratification tools known to the review team and provided by ACI.

A total of 30 papers and four research protocols were included for review including eight outcome-based evaluations using some form of comparison group; four qualitative evaluations; two comparative case studies; six descriptive case studies; five reviews of tools and five implementation guides.

Question 1: What system-wide risk prediction strategies or approaches have been implemented and evaluated in pre-hospital and hospital contexts?

- **Papers included in the review reported on the use of 20 different risk stratification tools.**

These tools vary in terms of origin of development (public/private/academic), how the tools can be purchased/licensed for use, the variables used to populate the tool, how they can be adapted for use in local contexts and how results can be accessed and manipulated by end users.

- **We are aware of the existence of considerably more risk stratification tools than were reported in the evaluation literature, suggesting that while risk stratification tools have been developed and used widely, there has been little reported evaluation of how they are implemented in real-world settings.**

We found eight papers reporting outcomes-based evaluations, six of which used randomised or cohort controlled study designs. Their purpose only partially overlapped with the core questions addressed in this review. These studies did provide evidence that:

- **The use of risk stratification tools in combination with a care management plan can improve patient outcomes.**

- **However, there is equivocal evidence to suggest that the use of a risk stratification tool just to determine eligibility for managed care has an added benefit.**

- **The use of a risk stratification tool to determine components of a care management plan may contribute to reductions in hospital readmissions, health service use and improved patient outcomes.**

Evidence from evaluation in this area is scattered yet rapidly emerging. We found protocols of four high potential trials of the implementation of risk stratification tools that are due to report within the next 12 months; all of which intend to take a comprehensive, mixed-methods approach to examining a broad range of aspects related to the implementation of risk stratification tools closely aligned to the objectives of this review.

- **The ACI may wish to consider an update of this review at a future date when the results of these studies become available.**

Question 2: Of these strategies or approaches, what key factors have been identified as critical enablers and/or barriers to successful implementation at a system level?

Evidence of critical enablers and barriers to successful implementation was weak and relied on descriptive case studies and qualitative studies. We identified four key areas of implementation in which there are critical enablers and/or barriers.

1) The engagement of clinicians in tool implementation, refinement and end use

- **Clinicians who already had an understanding and sympathy for population health perspectives were the easiest to engage**

- **Investment in education and training may increase clinician engagement**

- **Clinicians are more likely to use a risk stratification tool if they are given some independence to access and use data from the tool**

- **A system that blends the use of a risk stratification tool with clinical judgement may improve acceptance among clinicians**

- **The introduction of a risk stratification tool can lead to quite different patterns of patient flow. Existing systems (and staff) can be overwhelmed without careful planning.**

2) The context in which the tool was introduced into the health care system

- **Introducing a risk stratification tool within a clearly articulated broader strategy with two-way communication between planners and healthcare providers can facilitate success. Related initiatives should be developed in parallel**

- Some examples of successful implementation could be characterised as 'top-down' with centralised data collection, distribution and funding

- The wider operating environment can act as a barrier or facilitator to success; factors include incentives in other parts of the health care system that might encourage/discourage different models of care.

3) Data requirements and characteristics of the tool

- Commissioners have the option to develop a new tool or purchase an existing tool and adapt it locally. There is no strong evidence to indicate which option is more cost-effective

- Reliable up-to-date data is required to populate risk stratification tools

- Linked, or preferably centralised, data collection systems facilitate prompt, accurate prediction

- Tools that have been adapted to local contexts by using locally relevant indicators and having been validated locally may be more reliable. Tools developed in other countries may over- or under-predict risk when applied locally

- Some tools that are intended to be populated with clinical data gathered directly from the patient can be adapted for use with administrative data.

4) Equity issues

- The collection and linkage of patient data requires strong data protection systems. Data protection laws and regulations increase the complexity of the environment in which risk stratification tools are implemented

- More targeted 'impactibility' models (that identify patients who may benefit most from a particular intervention) are contentious and rarely debated in the literature. Some jurisdictions have rejected this approach on equity grounds.

Question 3: How were these models adjusted or adapted during or after evaluation to take into account critical enablers and barriers?

Changes during implementation or after evaluation were rarely discussed in the identified studies. Evidence is primarily from descriptive case studies only and therefore weak.

- In some jurisdictions the predictive accuracy of an 'off the shelf' risk stratification tool was found wanting when applied in local contexts. Tools were adapted using locally relevant indicators and validated locally

- Most tools are re-calibrated on a regular basis (every 2–4 years)

- **In some jurisdictions, the introduction of training and information packages for clinicians increased engagement with, and acceptance of, a risk stratification tool**

- **In some jurisdictions, the implementation of the tool was changed to formally include clinical judgement in the decision-making process, either at the point of decision to treat, or by establishing new criteria for inclusion/exclusion through surveying clinicians' opinions**

- **The mechanism through which tool outputs are distributed to clinicians has evolved. In early approaches data was sent to clinicians via email or mail, resulting in a time-lag. More recently clinicians can access tool outputs through secure web-based user interfaces**

- **The frequency at which risk stratification algorithms tend to be run has evolved from periodic (six-monthly, monthly) to continual.**

Question 4: What key learnings are to be derived from implementing strategies or approaches to risk stratification, from a system-wide perspective?

Despite the lack of strong studies – and the dearth of Australian evaluations of risk stratification tools, some learning points can be extracted that are relevant to the NSW context.

- **A key decision in the approach to risk stratification is to decide between purchasing a ready-made commercial risk stratification tool or developing a new one. The literature demonstrates some of the benefits of starting afresh, especially in developing around local data sources and problems. The pitfalls are also clear, mainly around workforce and cost**

- **The design of a new tool or adaptation of a ready-made one will depend on ready availability of relevant linked data, minimal expenditures and labour to link incompatible systems**

- **The risk stratification programs which met greatest acceptance and fewer teething problems were embedded in clearly explained broader disease management and care integration strategies**

- **The risk stratification tools that won swiftest support from clinicians were designed with user-friendly portals so that health practitioners and, where possible, patients could access useful information, often linked to decision aids relevant to the patient's risk**

- **Data protection and privacy issues need to be sorted out very early**

- **Health care practitioners were more likely to embrace new methods of case finding if they were consulted at every stage. If they could see a clear benefit to their own patients, they were much more prepared to make some of the changes in practice required and less likely to see risk stratification tools as an attack on clinical judgement**

- **Considering the lack of publicly available information on the implementation of risk stratification tools in real-world settings, any adoption of such an approach in NSW should include rigorous evaluation.**

2   Background

This review has been commissioned by the New South Wales Agency for Clinical Innovation (ACI) and the Sax Institute to inform decisions on the development or adoption of risk stratification tools for potential application in NSW.

The focus of this review (which will complement others) is the <u>implementation</u> of risk stratification tools. Risk stratification models are used for predicting events such as unplanned hospital admissions, which are undesirable, costly and potentially preventable. Risk stratification is central to linking people identified at the highest risk of health deterioration to the most appropriate evidence-based integrated care strategies.

The primary aim of the review is to identify the major issues that arise in implementation, how these have been addressed, and to understand their relevance and potential applicability in the NSW context. The review is intended to identify critical enablers and barriers to implementation from a system-wide perspective, for consideration in a NSW risk stratification plan.

3 Review questions

1. What system-wide risk prediction strategies or approaches have been implemented and evaluated in pre-hospital and hospital contexts?

2. Of these strategies or approaches, what key factors have been identified as critical enablers and/or barriers to successful implementation at a system level?

3. How were these models adjusted or adapted during or after evaluation to take into account critical enablers and barriers?

4. What key learnings are to be derived from implementing strategies or approaches to risk stratification, from a system-wide perspective?
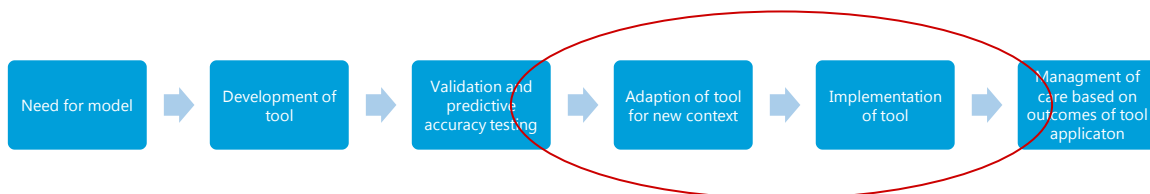
4 Approach to the review

We use the term 'risk stratification tool' to mean all models, tools and systems that use algorithms to predict future risk of health service utilisation. These algorithms include variables and equations designed to protect against the oversimplification and inaccuracy of simple threshold models, e.g. they take into account the problem of 'regression-to-the-mean', where high users of health services in any one given year tend not to be high users in the previous or following year.

We presume some knowledge of stratification tools and the types of variables used to populate them. We therefore provide only limited information on the precise data required for each risk stratification tool and their predictive accuracy. Reports on the development and validation of virtually all of the tools reviewed here can be found in the peer-reviewed literature.

To define the scope of the review in terms of the 'implementation' of risk stratification tools, we examined the spectrum of literature on risk stratification and determined the specific field of interest for this review (See Figure 1).

Papers that studied or described the adaption of a standard risk stratification tool for a new context or the implementation of a new tool were of primary interest. Papers that focused on testing the predictive accuracy of a tool or the management of care following the use of the tool were only of interest if they also addressed adaptation or implementation. Papers that described care management following population risk stratification were only included if the use of the tool was sufficiently described as part of the intervention/case description.

Figure 1: Spectrum of literature on risk stratification and area of interest for review

Need for model → Development of tool → Validation and predictive accuracy testing → Adaption of tool for new context → Implementation of tool → Managment of care based on outcomes of tool applicaton

5 Search methods

Our search strategy followed a two-pronged approach.

First, a systematic search was conducted in Medline (via OvidSP), Embase, Scopus, the Cochrane Library and CINAHL databases with the following search terms:

Risk stratificat* OR Risk profil OR Population profil OR Population segment* OR Predictive risk OR Predict*
model OR Risk predict* OR Risk Population* OR Risk model* OR Stratificat* strateg*
AND
Health service* OR Managed Care OR Integrated Care OR Primary Care OR Primary Health Care OR Aged
Care OR Hospital OR Health System OR Population health
AND
Models OR Tools OR Program OR System

Truncation was applied to capture various word endings and spellings. Subject headings were applied where available in the respective database and adjusted to interface-specific demands. Full citation searches were applied in preference to keyword/title where possible. Filters applied included publication date 2000–2015 and available in English language. A complete list of search terms for each database is outlined in Appendix 1.

Database searches returned the following results: Medline 578 citations; Embase 646; Scopus 185, Cochrane Library 23 and CINAHL 707 producing a total of 2139 results.

Second, focused searches were conducted in Medline, Embase, Google scholar, google and Medline for the following risk prediction models: "PARR", "SPARRA", "SPARRA-MH", "Combined Predictive Risk Model" "Hospital Admission Risk Prediction", "Adjusted Clinical Groups", "LACE index", "Prism", "EARLI", "Charlson Co-Morbidity", "PEONY", "OPTUM", "Community Assessment Risk Screen (CARS)", "Pra", "PraPlus", "Adjusted Clinical Groups", "Krumholz Model", "Qadmissions", "Framingham calculator" "ANDROD", "APACHE" "Risk Stratification Indices", "Risk Quantification Index"

This returned an additional 31 results.

The total combined search results totalled 2170 citations that were downloaded to EndNote to be assessed for inclusion in the review. After removal of duplicates the total number of citations was 2107.

A title and abstract search eliminated 2051 references and a full text assessment eliminated a further 22 papers based on the following criteria:

In alignment with the approach to the review outlined above, we included include papers that addressed:

- Adaptation of a risk stratification tool for real world application
- Implementation of a risk stratification tool.

We excluded papers that solely addressed:

- Needs assessment or general potential applicability of risk stratification tools
- Development of a tool
- Validation of a tool/predictive accuracy testing
- Care management following the use of risk stratification tools, but not the use of the tool itself
- Risk predictive tools used exclusively within the hospital setting "on the wards".

We were aware that there would be few rigorous evaluations that assess the impact of implementation of risk stratification tools. We therefore conducted our search broadly to include:

- Evaluations using control (randomised, pseudorandomised, cohort, historical), multiple baseline, and interrupted time series designs
- Qualitative studies/surveys
- Comparative case studies
- Descriptive case studies/reports
- Implementation guidelines
- Study protocols
- Reviews of models.

We excluded:

- Commentary
- Newspaper and magazine articles
- Powerpoint presentations
- Abstracts

Additional inclusion criteria were:

- Implementation of tool in an OECD country

A total of 30 papers and 4 protocols were found suitable for inclusion in the review including comparison controlled evaluations with various study designs, qualitative evaluations, comparative case studies and single descriptive case studies (See Appendix 3). We also found five reviews of tools and five implementation guides (see Assessment under Question 1). See Prisma flowchart in Appendix 2.

Table 1: Classification of papers included in review

Type	Papers	Protocols
Evaluations of use of tool and associated care/response using control, multiple baseline or interrupted time-series designs	8	2
Qualitative evaluations	4	1
Comparative case studies	2	1
Descriptive case studies	6	
Reviews of tools/brief multiple case studies	5	
Implementation guides	5	
TOTAL	**30**	**4**

6 Question 1:

What system-wide risk prediction strategies or approaches have been implemented and evaluated in pre-hospital and hospital contexts?

Key findings

- **Papers and protocols included in the review reported on the use of 20 different risk stratification tools.**

These tools vary in terms of the origin of development (public/private/academic), how the tools can be purchased/licensed for use, the variables used to populate the tool, how they can be adapted for use in local contexts and how results can be accessed and manipulated by end users (See Table 2, page 26).

- **We are aware of considerably more risk stratification tools than were reported in the evaluation literature, suggesting that while risk stratification tools have been developed and used widely, there has been little published documentation on how they are implemented in real world settings.**

We found eight papers reporting outcomes-based evaluations, six of which used randomised or cohort controlled study designs. Their purpose only partially overlapped with the core questions addressed in this review. These studies did provide evidence that:

- **The use of risk stratification tools in combination with a care management plan can improve patient outcomes**

- **However, there is equivocal evidence to suggest that the use of a risk stratification tool solely to determine eligibility for a managed care program has a positive effect on patient outcomes**

- **The use of a risk stratification tool to determine components of a care management plan may contribute to reductions in hospital readmissions, health service use and improved patient outcomes.**

Evidence from evaluation in this area is scattered yet rapidly emerging. We found protocols of four high potential trials of the implementation of risk stratification tools that are due to report within the next 12 months; (See Question 1 Assessment, page 23) all of which intend to take a comprehensive mixed-methods approach to examining a broad range of aspects related to the implementation of risk stratification tools closely aligned to the objectives of this review.

- **ACI may wish to consider an update of this review at a future date when the results of these studies become available.**

Overview

We found a total of six evaluations using a control, one interrupted time-series evaluation and one multiple baseline evaluation, making a total of eight evaluations that measured the impact of implementing a risk stratification tool against quantifiable outcomes. We also found four qualitative evaluations, two comparative case studies and six descriptive case studies. Four protocols on mixed-methods evaluations were found. Papers and protocols included in the review reported on the use of 20 different risk stratification tools.

Evaluation studies and tools

Of the total of eight studies that measured the impact of implementing a risk stratification tool on quantifiable outcomes, only one study [1] used a control group that did not receive any risk stratification.

- 1248 patients with diabetes under the care of GPs in Hong Kong were randomly selected for participation in the study. Participants were matched by age, sex, and HbA_{1c} level at baseline with a further 1248 patients as the usual care group. Patients in the intervention group were risk stratified using the **Joint Asia Diabetes Evaluation (JADE) Risk Engine**, a tool populated by clinical assessment (including BMI, waist circumference, BP, HbA_{1c}, full lipid profile, renal function) and history of previous complications as 'very high', 'high', 'medium' and 'low' risk. [1] Different management strategies (such as nurse, consultant, allied health visits and a patient empowerment (education) program) were applied within the Risk Assessment and Management Program for Patients with Diabetes Mellitus (RAMP-DM) program according to each patient's profile. At 12 month follow up, the RAMP-DM group had significant net decrease in HbA_{1c}, predicted CHD and stroke compared to the usual care group.

In the remaining seven studies, which used a control, multiple baseline or interrupted time-series design, both the intervention and usual care groups were stratified using the adopted tool and only the managed care program after stratification comprised the intervention. Lessons from these studies therefore need to be interpreted carefully. Positive outcomes in the intervention group indicate benefits of implementing a managed care program that includes the use of a risk stratification tool, but cannot attribute results to either the care package or risk stratification tool alone.

Amongst these studies, four [2–5] involved interventions where the risk stratification tool was used solely to determine eligibility to receive a care package. In these studies there were either no, or only small, benefits for the intervention group over control groups.

- In Nairn, Scotland, two cohorts of approximately 10,000 patients from two primary care practices with similar catchment and geographical characteristics were risk stratified using the **Nairn Case Finder**. [2] Two groups comprising 96 high-risk patients were matched for age, sex, multiple morbidity indexes, and secondary care outpatient and inpatient activity. Only patients from the intervention practice received an "Anticipatory Care Plan" comprising a case manager, allied health visits and a patient interview to identify unmet need. Results were presented pre-post and control compared. Mortality rates in the two cohorts were similar, but the hospital bed days used in the last

three months of life were significantly lower for the decedents with an Anticipatory Care Plan.

- Medicare beneficiaries aged 70 and older in Ramsey County, Minnesota, USA were stratified using a self-completed **Probability of Readmission (Pra)** instrument survey received in the mail, resulting in a patient score between 0 (low risk) and 1 (highest risk). [3] All high-risk respondents (Pra >0.4) were telephoned to obtain baseline measurements. Patients were matched according to Pra stratification block and randomised. Primary care physicians for the control group were notified of their patients' high risk for repeat hospitalisations and thereafter received care their physician deemed appropriate. Intervention group patients received an interdisciplinary care package that included access to a geriatrician, nurse practitioner and a 24-hour on-call service. Mortality, use of health care services, and total Medicare payments did not differ significantly between the two groups. Follow up interviews found that patients in the intervention group were significantly less likely to lose functional ability.

- High-risk patients identified using the **LACE** (Length of Stay, Acuity of admission, Comorbidities, Emergency department visits) tool administered at discharge in four hospitals in the Toronto Central Local Health Integration Network [4] were randomly allocated to either admission to a Virtual Ward or usual care. Patients assigned to a Virtual Ward received telephone follow-up, home visits or clinic visits. An inter-professional team met daily at a central site to discuss management plans. Usual care involved a structured discharge summary, counselling from the resident physician, and arrangements for home care as needed. There was no statistically significant difference between the groups on 30 day, 60 day, six month or one year readmission.

- Eight community-based primary care practices in Baltimore, MD and Washington DC, USA participated in the Guided Care program study [5]. Patients of the participating physicians were selected for initial screening according to age (>65) and type of insurance coverage. The **Hierarchical Condition Category (HCC)** was applied using administrative data. Patients were potentially eligible if their HCC risk ratios were in the highest quartile of the population of older patients covered by their health care insurer. Usual care was given to 419 patients and 485 patients received a Guided Care package comprising eight nurse-led services. In intention-to-treat analyses, Guided Care did not significantly improve participants' functional health, but it was associated with significantly higher participant ratings of the quality of care.

Three studies [6-8] involved interventions where the risk stratification tool informed not only eligibility to receive a managed care package, but also the content of that package. These studies reported some improvements in hospital readmission rates.

- Kaiser Permanente Southern California (KPSC) used the **LACE** tool to stratify patients into low (LACE score 0-6), medium (LACE score 7-10) and high (LACE score 8 -11) risk. [6] Different bundles of care forming part of the "Transition in Care" program were offered to patients accordingly with low-risk patients receiving 1) a standardised discharge summary including the tool result; 2) medication reconciliation and 3) access to a transition hotline. Medium-risk patients had, in addition to the interventions above, access to a post hospital visit from a physician within 14 days and high-risk patients within seven days. High-risk patients also received a follow-up call within 72 hours from discharge; a palliative care consult (if needed) and a complex case conference.
The program was implemented in all 13 KPSC medical centres which collectively discharge

approximately 40,000 patients on medical risk plans each year. The intervention was introduced in all centres in the first quarter of 2012. Readmission rates from December 2010 to November 2012 decreased from approximately 1.0 to 0.80 and 12.8% to 11%, respectively.

In this study, LACE was first tested for its applicability and predictive ability with a retrospective study applying it to 30,000 KPSC Health Plan discharges over a 12-month period. To ease implementation, the LACE calculator was made available on the KPSC Electronic Medical Record and was automatically included in each patient's daily note and discharge summary.

- For the Indiana Chronic Disease Management Program (ICDMP), automated queries of Medicaid claims were created to identify people with diabetes and CHF based on ICD-9 or disease specific prescriptions in the previous 12 months. [8] The patient lists were sorted by practice location and county. Eligible participants were informed by mail. A **purposefully developed risk stratification tool (ICDMP tool)** was used to assign participants to different program services (nurse care managers to highest risk 20%; telephone care coordinators to remaining 80%). The Regenstrief Institute (academically affiliated research organisation) was engaged to develop the risk stratification tool with an algorithm based on two years of retrospective claims data using three predictors 1) total net Medicaid claims in past 12 months; Medicaid aid category (eg. 'aged' or 'disabled'); total number of unique medications filled in past year. Based on the phased implementation of the program in three regions of the state (Central Indiana in July 2003, Northern Indiana in July 2004 and Southern Indiana October 2004), 14 repeated cohorts of Medicaid members were drawn over a period of 3.5 years and the trends in claims were evaluated using a repeated measures model. The evaluation found a flattening of cost trends between the pre- and post-ICDMP initiation periods and remained flat in the final year of follow up.

- A purposefully developed risk stratification tool based on the American Diabetes Association Clinical Practice recommendations (henceforth **ADACP tool**) was implemented as part of a trial of a comprehensive diabetes program within a managed care organisation (MCO) in the US. [7] Adults with diabetes mellitus enrolled in two clinics (N=740, 370 in each clinic) received the intervention. Data from 623 members at a third clinic acted as a control group. Patients were stratified into high-, moderate-, or low-risk groups within disease categories. Interventions were based on previously agreed-upon standing orders (protocols) after approval from the primary care physician. Clinical outcomes as well as patient satisfaction (questionnaire) were measured at baseline and 12 months. Significant improvements were found in the intervention groups for glycaemic control and patient satisfaction as well as compliance with treatment protocols.

We found that the controlled or longitudinal studies described above offered no conclusive evidence of the benefits or limitations of implementing risk stratification tools in real-world situations. However the use of risk stratification tools in combination with a care management plan may offer some patient outcome benefits. The use of a risk stratification tool to determine components of a care management plan may contribute to reductions in hospital readmissions, health service use and improved patient outcomes.

We found four qualitative evaluations of the implementation of risk stratification tools. [9-12] These studies aimed to provide specific insights into factors influencing successful implementation of risk stratification tools by researching the experiences of end users. While the level of evidence is weak, they uncovered high promise indicators of real world barriers and facilitators to successful implementation.

- In the Basque Country, Spain, an adapted risk stratification tool based on the **Johns Hopkins University Adjusted Clinical Groups (JHUACG)** model was introduced in several primary care practices. [9] Three focus groups were conducted exploring clinicians' opinions and experiences related to the tool and its implementation in their daily practice. A purposive sample of 12 GPs and 11 primary care nurses participated in the groups. The study identified several enablers and challenges to implementation and the need to frame the implementation of a new risk stratification tool within a wider strategy (see Review Question 2).

- The **Case Smart Suite Germany (CSSG)** risk stratification tool was used in a cohort of patients insured with the German General Regional Health Fund (AOK) and registered at one of 10 small to mid-sized primary care practices in Munich, Germany to select patients for a managed care scheme. [10] Twelve primary care physicians were asked to identify 30 patients from the same cohort for inclusion in the same scheme. The primary care physicians (PCPs) were given the opportunity to compare their own selection with that of the risk stratification tool before engaging in a semi-structured interview on how primary care physicians experienced the use of CSSG compared with using clinical judgement. Overall, PCPs rated the approach as a useful tool to identify patients likely to benefit from case management. However, they were concerned about time lags between data analysis and patient recruitment.

- The evaluation of the use of the **Prism** tool in Demonstrator Sites for the Wales NHS Chronic Disease Management Program sought to identify the health and social care staff using or otherwise engaging with PRISM and its outputs; describe the ways in which Prism has been used and gather views on current and potential use of the tool at practice and population levels. [11] Focus groups and interviews were undertaken with staff in the 13 general practices taking part in the demonstrator testing of Prism, including locality planning coordinators and GP leads. The study found that first impressions of Prism were mixed and often improved following further exposure to the tool. Various enablers and barriers were identified (See Review Question 2).

- **Scottish Patients at Risk of Readmission and Admission (SPARRA)** is a risk prediction tool implemented for the whole of the Scottish population to predict an individual's risk of being admitted to hospital as an emergency inpatient within the following year. [12] In 2008, NHS Scotland's Information Services Division that developed and has carriage of the tool undertook a qualitative survey of tool users at Community Health Partnerships (CHPs), Health Board, and GP level. Twenty five survey respondents (83% response rate) reported on: 1) Individuals to whom SPARRA data is forwarded, 2) local modifications to the output, 3) local additions to the output, 4) data sharing protocols in place, 5) local uses of SPARRA data and 6) suggested additional data/information to be included in the SPARRA output. The study found that patterns of dissemination were variable and complex and in some instances data was not actually reaching intended end users. The study found that end users were interpreting SPARRA data correctly and making suitable adjustments. Prescribing data was identified as highly desirable to augment the current SPARRA methodology and the study found improvements in functionality of SPARRA would be desirable to allow end users to filter or highlight patient groups of specific interest (see Review Question 2).

The qualitative evaluations above provide no conclusive evidence of the most critical barriers or enablers to intervention as they apply to any one particular tool. However, they do highlight potential issues for consideration in the NSW context (See Review Question 2 and 4).

We identified two comparative case studies of implementation of risk stratification tools. In these studies certain differences in the implementation of the tool are compared across localities and considered for possible effect on differences in uptake, acceptance, sustainability and outcomes. The level of evidence produced is weak due to the risk of confounding factors across case study contexts. Nevertheless comparative case studies offer insights into the potential implications of different contexts and implementation practices.

- Three adaptations of the "Virtual Wards" program in Croydon, Devon and Wandsworth, UK used stratification tools to determine catchment areas for Virtual Wards and select patients for admission. [13] The **Combined Predictive Risk Model** was used in Croydon, where programs had already been implemented using GP data to improve care. An adapted version with a new user interface was created for use in Devon (henceforth the **Devon Combined Predictive Model**) and the **PARR** model was used in Wandsworth. In Croydon the program was fully funded through the Primary Care Trust while in the other two cases the program was co-funded with the local council. The nature of the Virtual Ward program differed in terms of composition of the multidisciplinary team, leading Virtual Ward staff (community matrons, ward clerks, ward GP) and timing of implementation. The study compared the operating environment, organisational culture, the extent to which 'activated patients' were encouraged, culture of integration/GP involvement, data sharing and program champions. The study identified a number of barriers and enablers to implementation in each case (See question 2).

- The three cases described above are also included in a comparative review of six managed care programs including North Somerset UK (using no risk stratification tool), Toronto Canada (using the **LACE** tool) and New York City USA (using a purpose build Medicaid data model for their **"Hospital2Home" scheme**). [14] The managed care schemes varied in terms of the composition of multidisciplinary teams, role and discipline of ward coordinators, (eg. In New York the case managers came from the social sector due to housing problems of a large number of the patients), and the size of the 'ward'. The implementation of the risk stratification tool differed in terms of whether a predictive model was used at all; whether an impactibility scale was used to further identify patients most likely to benefit from care (eg. Hospital2Home, New York) and the extent to which a predictive model was used to discharge patients from the Virtual Ward (Devon, Croydon).

We identified six papers reporting descriptive case studies of risk stratification tools implemented in real-world settings. Although the strength of evidence emerging from these case studies is weak, they offer the richest insight into the range of factors that were perceived to enable or facilitate successful implementation of risk stratification tools. In some cases, the descriptive case studies offered in depth insights into how risk stratification tools were implemented in the controlled/comparative studies outlined above. We outline these case studies briefly below.

- Challenges to the implementation of the 'Virtual Ward' model of managed care described above are outlined in a case study by Lewis et al. [15] The two main challenges outlined include the reluctance of some GPs to allow patients to be selected purely on the basis of a predictive risk

model **(Combined Predictive Risk Model** or **PARR**), and the request by some for the right to select which patients should be offered admission. In response, a series of presentations to GPs set out the evidence base for predictive models, in particular, findings from a literature review (conducted by The King's Fund for the Department of Health) that suggested that predictive models could be more accurate than clinical opinion in forecasting risk of future hospitalisation. The second challenge identified was in communicating the Virtual Ward concept to community-based staff; staff initially found the concept was somewhat abstract and difficult to grasp.

- The **systemic coronary risk evaluation (SCORE) tool** was applied to risk stratify 1011 patients living in Cyprus, diagnosed with diabetes mellitus, hypertension or hyperlipidaemia [16]. The results of the stratification were used to assess the quality of care for patients with these conditions in the country and inform new care policy decisions. Suboptimal control and under-treatment of patients with cardiovascular risk factors were found, as well as under-prescription of antihypertensive drugs, lipid-lowering drugs and aspirin for all three high-risk groups. Improvement of documentation of clinical information in the medical records as well as GP training for implementation and adherence to clinical practice guidelines were recommended as potential areas for further discussion and research.

- Rosenman et al. describe the implementation of the purposefully built risk stratification tool in the Indiana Chronic Disease Management Program **(ICDMP tool)** mentioned above [17]. The algorithm was developed based on two years of retrospective Medicaid claims data and used three predictors: total net Medicaid claims in past 12 months; Medicaid aid category (eg. 'aged' or 'disabled') and total number of unique medications filled in past year. The Indiana state Medicaid agency commissioned development of the tool to the same vendor that provided a medical records system for a large urban group practice within the state (Regenstrief). Consultation with end users informed the development of the tool. Automated queries are run every 3–6 months to identify eligible patients, with notifications going directly to patients in the mail. Patients entering the program are then risk stratified to assign participants to different program services (nurse care managers to highest risk 20%; telephone care coordinators to the remaining 80%).

- Clalit Health Services (Israel's largest managed care organisation) sought to adapt the **Johns Hopkins University Adjusted Clinical Groups (JHUACG) risk model** for implementation to select patients for a multi-morbid care management program. [18] Six physicians were surveyed on characteristics of their current (2012) patients to elicit clinical considerations for high-risk patient identification. Separately the JHUACG tool was used to risk stratify patients from 2010-2011 using data from the Clalit Health Services central administrative data set. Clinically-defined exclusion criteria obtained from the physician survey were used to revise the final list of patients to receive a care management program.

- In Valencia, Spain, the **Pra** and **Community Assessment Risk Screen (CARS)** tools were used to detect patients at risk of hospital readmission in a sample of 500 elderly people (65+) from the VHS in Spain. [19] Both of these tools, when used off-the-shelf, were designed to be fulfilled either by post or telephone interview (Pra) or by interview with medical staff (CARS). The Valencia health service trialled using administrative data to populate the tools, supplemented by two self-report items in the case of the Pra tool. Both tools implemented this way were found to have an acceptable level of accuracy in the prediction of hospital admissions.

- The Geisinger Clinic, comprising 40 community-based primary care practices in Pennsylvania, undertook a feasibility test of the use of the **Framingham Risk Score (FRS)** to risk-stratify patients and involve them in shared decision making. [20] Patient-reported data was obtained via a touchscreen device-administered questionnaire in the practice and was automatically combined with electronic health record (EHR) data to calculate risk. Higher-risk patients viewed an interactive web-based tool and chose treatment options to modify risk factors. A real-time simulation indicated directly to patients their expected outcomes when the treatment option was followed. Following a trial period during which 1068 patients used the device, the system was considered feasible for full implementation. The Framingham Risk Score was modified for final use (two variables added –alcohol use and family history, two variables changed from binary to continuous measurement – smoking and diabetes, and one variable omitted – left ventricular hypertrophy (LVH) on electrocardiogram). The modified FRS was used to calculate both the absolute 10-year risk and an associated relative risk of a cardiac event for risk stratification.

Assessment

We are aware of the existence of considerably more risk stratification tools than were reported in the evaluation literature described above. This suggests that while risk stratification tools have been developed and used widely, there has been little reported evaluation of how they are implemented in real-world settings. The literature on the development and validation (for predictive accuracy) of risk stratification tools is considerably more abundant but outside of the scope of this review.

While we found eight papers reporting outcomes-based evaluations, six of which used randomised, matched or cohort controlled study designs (NHMRC levels II and III-2), [21] their purpose only partially overlapped with the core questions addressed in this review. While we only included studies that provided some information on context and implementation of the risk stratification tool, this was not the main subject of investigation. This diminished relevance, or 'indirectness' [22] means that these studies contribute only a limited understanding to what contributes to successful implementation of risk stratification tools in real-world settings and critical enablers and barriers.

These studies do provide evidence that the use of risk stratification tools in combination with a care management plan may offer some patient outcome benefits and that the use of a risk stratification tool to determine components of a care management plan may contribute to reductions in hospital readmissions, health service use and improved patient outcomes. There is equivocal evidence to suggest that the use of a risk stratification tool solely for determining eligibility for managed care has a positive effect on patient outcomes.

Evidence from qualitative studies and descriptive case studies identify a range of factors that contribute to successful implementation. Despite a weaker study design (unclassified in traditional evidence hierarchies such as that from the NHMRC) they provide the most promising evidence for this review to answer questions of barriers and enablers to successful implementation of risk stratification tools in the real world. They are therefore heavily drawn upon to respond to Review Questions 2 and 3.

Due to the small number of qualitative and case study papers found, we also draw lessons from an additional two types of papers in the remaining sections of this rapid review.

Five risk stratification tool implementation guides intended for Medicaid purchasers in the USA,[23] Commissioners in NHS England (two guides), [24, 25] Prism end users in Wales [26] and SPARRA end users in Scotland [12] were identified during the focused search. These guides only give an indication of the intended implementation process of various tools and thus do not provide quality evidence; however they do specify conditions for implementation that may be considered important enablers/barriers.

We also found five general reviews of the role of predictive risk stratification tools in healthcare and their intended use. [27-31]These reviews are not systematic reviews of controlled studies and do not provide a higher level of evidence than the articles described above. However, they do contain brief case studies, overviews of the predictive ability of various tools and policy-level analysis of key considerations when promoting and/or mandating the use of risk stratification tools.

Finally, we found that evidence from evaluation in this area is scattered yet rapidly emerging. We found protocols of four high potential trials of the implementation of risk stratification tools that are due to report within the next 12 months; all of which intend to take a comprehensive mixed-methods approach to examining a broad range of aspects related to the implementation of risk stratification tools closely aligned to the objectives of this review. The ACI may wish to consider an update of this review at a future date when the results of these studies become available.

- The PRISMATIC trial is currently underway led by the Centre for Health Information Research and Evaluation (CHIRL) at Swansea University, UK. [32] This trial will evaluate the implementation of the **Prism** risk stratification tool throughout Wales, UK. Primary care practices will receive access to the Prism tool and training randomly, and thereafter be able to use Prism with clinical and technical support. Costs, processes of care, satisfaction and outcomes at baseline, six and 18 months, using routine data and postal questionnaires will be assessed. Focus groups and interviews are being undertaken to elucidate experiences of using the by practitioners and policy makers. The 18-month intervention period has been completed and reporting is expected in 2015.

- **The Diabetes Population Risk Tool (DPortT)** predicts nine-year risk for diabetes and is being implemented in Ontario and Manitoba in Canada. [33] Predictive factors included are body mass index, age, ethnicity, hypertension, immigrant status, smoking, education status and heart disease. The planned evaluation will assess the effectiveness and impact of a proposed Knowledge-to-Action framework for facilitating the implementation of the tool and use observer notes, interviews and surveys to identify factors that facilitate uptake and overcome barriers to DPoRT use.

- The INTEGRATE study [34] will assess the use of the **Finnish Diabetes Risk Score (FINDRISC)** tool as part of the Personalized Prevention Approach for CardioMetabolic Risk (PPA CMR) scheme. The scheme will be offered in 40 general practices in the Netherlands, making up a representative sample of all Dutch general practices with regard to the distribution in rural/urban and solo/group practices. After an online risk estimation, patients with a score above the risk threshold will be offered detailed risk profiling and tailored care management. Lifestyle, health and work status will be measured at baseline and after 12 months.

- A European wide project, "**Activation of Stratification Strategies and Results of the interventions on frail patients of Healthcare Services (ASSEHS)**", has been established to assess the use of existing health risk stratification strategies and tools throughout Europe. [35] Multiple studies are anticipated with the first mapping the implementation stages of six risk stratification

tools used in Europe. First results are expected in 2015. Further work packages include the development of a consolidated standard for appraising stratification techniques; analysis of the feasibility of introducing stratification tools in healthcare including identifying barriers and facilitators; measuring impact of stratification tools on structure and processes of healthcare organisations; assessing impact of using stratification strategies and tools on health service resources, management and clinical practice, involving different health services and social actors, and primary and secondary care.

Table 2: Risk stratification tools evaluated in the review literature

Risk stratification tool	Studies	Developer/origin	Input data and implementation
Case Smart Suite Germany (CSSG)	Freund (2012)	Commercial developer. Verisk Health, Munich, Germany.	This tool may be purchased for use 'off-the-shelf' by healthcare providers and insurers. The algorithm used is similar to that of diagnostic cost groups. Inputs include ICD-10-German Modification (GM) diagnosis codes assigned in outpatient and inpatient settings, prior costs, hospital admissions and demographic data. Clinically similar ICD-10-GM codes are classified into diagnostic groups that are collapsed into diagnostic categories. [36] Generic models for adaptation in other countries are also available for purchase.
Combined Predictive Risk Model (CPRM)	Lewis (2010); Lewis (2013); Lewis (2012)	Publicly developed tool (Kings Fund UK and Health Dialog). Now de-commissioned.	An algorithm for predicting re-hospitalisation in the next 12 months intended for use by Primary Care Trusts and other NHS organisations in the UK where both primary and secondary data are available. Available for use by NHS organisations as a stand-alone string code; requiring the local build of a user interface. Allows segmentation of an entire NHS population (all patients registered with a GP) into relative risk segments.
Community Assessment Risk Screen (CARS)	Doñate-Martínez (2001)		This tool uses three variables to predict future hospitalisations: 1) pre-existing chronic diseases; 2) the number of prescription medications and 3) hospitalisations or ED use in the preceding 6–12 months. The score (0–9) is accumulative depending on the number or risk factors present. Data is obtained by medical staff directly from patients and the algorithm applied. In Valencia, the tool was adapted for use with administrative data. [37]
Diabetes Population Risk Tool (DPortT)	Rosella (2014)	Public tool developed by Canadian Institutes of Health Research and the Population Health Improvement Research Network	Calculates the future risk of diabetes, for diabetes-free individuals. Uses publicly available national population health surveys administered by Statistics Canada (Canadian Community Health Survey). Publicly available for download directly into SAS statistics software or as a formula. Can be used to predict cases or to attribute the contribution of specific risk factors (included in the algorithm) to population risk.
Devon Combined Predictive Model	Lewis (2012); Lewis (2013)	Adaptation of CPRM tool developed by NHS Devon, UK.	Predicts unplanned admission to hospital or an emergency re-admission in the following 12 months. This adaptation of CPRM added seven local factors as variables including length of registration with GP.
FINDRISC (Finnish Diabetes Risk Score)	Badenbroek (2014)	Publicly available tool developed in the Diabetes Prevention Unit, Department of Chronic Disease Prevention, National Institute for Health and Welfare, Helsinki, Finland	Questionnaire style risk stratification tool available for use or adaptation online. [38] Assesses an individual's risk of developing type 2 diabetes stratified as low, slightly elevated, moderate, high and very high. Included variables are: age, BMI, waist circumference, physical activity levels, consumption of vegetables, fruits or berries, high blood pressure requiring treatment, previous high blood glucose and family history.

Risk stratification tool	Studies	Developer/origin	Input data and implementation
Framingham Risk Score (FRS)	Jones, Shah, Bruce et al. (2011)	Developed as part of the Framingham Heart Study, Boston University. Algorithm publicly available.	The updated version of this algorithm (from 2002) uses eight variables to assess risk of developing cardiovascular disease in the next 10 years. Variable thresholds are calculated differently for men and women. The tool is open source and may be integrated into clinical decision support tools, other multi-faceted risk prediction tools or completed online for real time results using one of several user interfaces available online. Has been shown to overestimate risk when applied to patients in European settings.
Hierarchical Condition Category (HCC)	Boult (2013)	Developed by and for the Centres for Medicare and Medicaid Services, USA.	Measures the burden of 70 disease categories that are correlated to diagnosis codes. Introduced in 2004 in the Medicare and Medicaid systems as the basis for capitation and reimbursements. The HCC for each patient is captured every 12 months and forms the basis of payments for the following 12 months.
Johns Hopkins University Adjusted Clinical Groups	Cohen, Flaks-Manov, Low et al. (2015); Arce, De Ormijana, Orueta, et al. (2014)	Developed at Johns Hopkins University with commercial licence rights.	Software package available for US or international licence (currently available Version 9). Uses various inputs that can be adjusted according to setting such as: age, gender, total disease burden, medical conditions, population markers, resource use and medications. Available as a stand-alone product or a part of a service delivery package and electronic medical record administration.
Joint Asia Diabetes Evaluation (JADE) Risk Engine	Jiao, Fung, Wong et al. (2014)	Privately developed tool: Asia Diabetes Foundation and the Chinese University of Hong Kong.	A risk stratification tool that forms part of a web-based portal of care protocols, clinical decision and self-management support. Patients consent to enrolment in the program, from which point medical data are carried within the portal. A yearly health assessment is carried out and data entered into the portal which is cross-matched with administrative data to measure risk of five-year probability of major clinical events. The full program is accessed by GPs through a secure web portal and key patient data are available for viewing at care appointments.
LACE	Dhalla, Lewis 2012; Tuso, Huynh, Garofalo (2013)	Publicly developed in Ontario, Canada.	Data inputs are length of stay ("L"); acuity of the admission ("A"); comorbidity of the patient (measured with the Charlson Comorbidity Index score) ("C"); and emergency department use (measured as the number of visits in the six months before admission) ("E"). Intended to be administered within the hospital at the point of discharge.
Nairn Case Finder	Baker A, Leak P, Ritchie LD et al (2012)	Public developer. NHS Scotland Highland Health Board	Tool originally developed for Lodgehill Clinic in Nairn and measures risk of an unplanned admission to hospital in the subsequent 12 months. Primary care data are taken from the country-wide GP medical records system "General Practice Administration System for Scotland" (since changed for use with current system "GP Vision"). Primary care variables include age, sex, and chronic disease status. Secondary care data were taken from the NHS Highland Patient Administration System and include outpatient attendance and unplanned admission to hospital in the previous two years. The tool was run monthly and GPs were provided with lists of at risk patients.

Risk stratification tool	Studies	Developer/origin	Input data and implementation
PARR (Patients at Risk of Readmission)	Lewis (2012); Lewis (2013)	Publicly developed tool (Kings Fund UK and Health Dialog). Now de-commissioned.	Public risk stratification tool intended to be used by Primary Care Trusts in the UK. Produces a patient 'risk score' showing a patient's likelihood of re-hospitalisation within the next 12 months. Risk scores range from 0–100, with 100 being the highest risk. PARR1 uses data on prior hospitalisations for certain 'reference conditions' to predict risk of re-hospitalisation while PARR2 uses data on any prior hospitalisation to predict risk of re-hospitalisation. Further iterations of PARR (including PARR-30) were developed. The tool originally did not come with an in-built user interface, although two have been developed (PARR + and PARR ++.)
Prism	Hutchings, Evans, Fitzsimmons (2013); Kingston: 2010; Smallcombe, Burge-Jones (2013).	Public tool commissioned by NHS Wales Informatics Service from King's Fund and Health Dialog.	Uses 22 variables from GP systems, eight from hospital inpatient record, three demographic variables, data of outpatient visits following ED visits and the Welsh Index of Multiple Deprivation to identify likelihood of an emergency hospital admission over the next 12 months. Both absolute risk (four risk levels based on percentage risk score) and relative risk (four risk levels based on risk score relative to the practice population) are measured. Care providers register for access and use Prism through a password-protected website. End users can view population level trends, view patient risk data (by entering a NHS number) or filter populations by risk level or other criteria.
Probability of Readmission (Pra)	Donate-Martinez; Boult (2001)	Developed at University of Minnesota. Johns Hopkins University holds exclusive rights from the University of Minnesota to sublicense to others.	Estimates probability of hospital readmission within four years. Inputs include age, gender, poor self-rated general health, availability of an informal caregiver, having ever had coronary artery disease, having had diabetes mellitus during the previous year, a hospital admission during the previous year, more than six doctor visits during the previous year. A more recent version of the tool (PraPlus) also includes questions about medical conditions, functional ability, living circumstances, nutrition and depression. Widely used in the USA. Use of the instruments must be under licence.
Systemic coronary risk evaluation (SCORE)	Zachariadou, Stoffers, Christophi et al. (2008)	Developed by a consortium of researchers for European Society of Cardiology funded by European Union BIOMED program	Developed in response to studies finding over-estimation of risk for CVD when tools developed in the USA were applied in European settings. Comprises paper-based risk charts for high-risk and low-risk European populations; national or regional risk charts based on published mortality data and a computer-based interface "Heartscore" for risk estimation data entry and calculation. The publicly available website includes a pro forma for calculating patients' risk, management advice and allows clinicians to save patient data (once registered with the site). A downloadable version is available.

Risk stratification tool	Studies	Developer/origin	Input data and implementation
Scottish Patients at Risk of Readmission and Admission (SPARRA)	National Health Service Scotland; Scottish Government Health Delivery Directorate: (2011).	Public developer, commissioned by Scottish Government Information Services Division from Health Dialog, UK.	SPARRA scores risk of admission in the prediction year and can be accessed securely online by authorised health care professionals in NHS Scotland Boards, Community Health Partnerships and GP practices. Three iterations of this tool have been developed. Version 1 stratified population >65 years, version 2 extended this to whole-of-population and version 3 includes new prescription data input. The algorithm is based on hospital inpatient admissions; community dispensed prescriptions; emergency department (ED) attendances; new outpatient attendances; and psychiatric inpatient admissions. Colour coded data visualisation is available.
A purposefully developed risk stratification tool for the Indiana Chronic Disease Management Program (ICDMP tool)	Katz, Holmes, Stump et al. (2009); Rosenman, Holmes, Ackermann (2006)	Commissioned by Indiana Medicaid from vendor Regenstrief Institute	Used to assign participants to different program services (nurse care managers to highest risk 20%; telephone care coordinators to remaining 80%). Algorithm based on two years of retrospective claims data 1) total net Medicaid claims in past 12 months; 2) Medicaid aid category (eg. 'aged' or 'disabled'); 3) total number of unique medications filled in past year.
A purposefully developed risk stratification tool based on the American Diabetes Association Clinical Practice (ADACP tool)	Clark, Snyder, Meek, et al. (2001)	Commissioned by Las Vegas Managed Care Organisation from Roche Diagnostics Corporation.	Uses laboratory tests and data from completed patient questionnaires to generate risk profiles (high-, moderate-, or low-risk) groups in seven categories: 1) glycaemic control, 2) cardiovascular disease, 3) nephropathy, 4) retinopathy, 5) hyper/hypoglycaemia, 6) amputation, and 7) psychosocial disorders. Data is entered and retrieved from a web-based interface.
A purposefully developed built Medicaid data model for the "Hosptial2Home" scheme	Lewis 2012	Adapted version of a reported algorithm developed at New York University, USA.	Identifies disabled adult patients eligible for mandatory managed care enrolment in New York, USA. Data is drawn from Medicaid Fee-for-Service claims. Variables include prior utilisation history, including frequency of and intervals between hospital admissions and ED visits, primary care and specialty care visits, and use of a broad range of other services (such as home care, personal care, rehab services, substance abuse services, prescription drugs, and so on), prior diagnostic history age, gender, race/ethnicity and geographical location. The tool is used to determine cost profiles and business case modelling.

7 Question 2:

Of these strategies or approaches, what key factors have been identified as critical enablers and/or barriers to successful implementation at a system level?

Key findings

Evidence of critical enablers and barriers to successful implementation was weak and relied on descriptive case studies and qualitative studies. We identify four key areas of implementation in which there are critical enablers and/or barriers.

1) The Engagement of clinicians in tool implementation, refinement and end-use.

- **Clinicians who already had an understanding and sympathy for population health perspectives were the easiest to engage**

- **Investment in education and training may increase clinician engagement**

- **Clinicians are more likely to use a risk stratification tool if they are given some independence to access and use data from the tool**

- **A system that blends the use of a risk stratification tool with clinical judgement may improve acceptance amongst clinicians**

- **The introduction of a risk stratification tool can lead to quite different patterns of patient flow. Existing systems (and staff) can be overwhelmed without careful planning.**

2) The context in which the tool was introduced into the healthcare system

- **Introducing a risk stratification tool within a clearly articulated broader strategy with two-way communication between planners and healthcare providers can facilitate success. Related initiatives should be developed in parallel.**

- **Some examples of successful implementation could be characterised as 'top-down' with centralised data collection, distribution and funding.**

- **The wider operating environment can act as a barrier or facilitator to success; factors include incentives in other parts of the healthcare system that might encourage/discourage the**

adoption of new models of care.

3)   Data requirements and characteristics of the tool

- **Commissioners have the option to develop a new tool or purchase an existing tool and adapt it locally. There is no strong evidence to indicate which option is more cost effective**

- **Reliable up-to-date data is required to populate risk stratification tools**

- **Linked, or preferably centralised, data collection systems facilitate prompt accurate prediction**

- **Tools that have been adapted to local contexts by using locally relevant indicators and validated locally may be more reliable. Tools developed in other countries may over- or under-predict risk when applied locally**

- **Some tools that are intended to be populated with clinical data gathered directly from the patient can be adapted for use with administrative data.**

4)   Equity issues

- **The collection and linkage of patient data requires strong data protection systems. Data protection laws and regulations increase the complexity of the environment in which risk stratification tools are implemented**

- **More targeted 'impactibility' models (that identify patients that may benefit most from a particular intervention) are contentiously debated in the literature. Some jurisdictions have rejected this approach on equity grounds.**

Overview

Evidence of critical enablers and barriers to successful implementation was weak and relied on descriptive case studies and qualitative studies. We identify five key areas of implementation in which there are critical enablers and/or barriers.

The studies surveyed here were predominantly single case studies, with a few comparative cases. The studies with the strongest focus on implementation used qualitative methods and these were more likely to look specifically at the risk stratification instrument [9,10,11,13,15]. Most of the qualitative research focused on how instruments were used (or not used) in practice, particularly the active involvement and support of clinical staff. The Indiana Chronic Disease Management Scheme study [8], was typical of most of the more quantitative studies, in this case based on Medicaid claims data. This cluster-randomised study provided the only longitudinal study, however, despite descriptions of the development of a new risk stratification instrument, the study focused on effects of the whole chronic care program. Several papers were reviews of a variety of studies [23, 24,25, 33]. These have been drawn on partly because of the lack of stronger evidence in some areas. However, the quality of the evidence they assemble is weaker than other studies.

- **Engagement of clinicians**

The Basque Country study [9], which looked at a population level adoption of the **Johns Hopkins University Adjusted Clinical Groups**, used qualitative methods to describe the engagement of clinicians. Those who already had an understanding and sympathy for population health perspectives were the easiest to engage. An investment in education was needed to bring others around.

Clinicians were also more likely to use the tool if they were given some independence to access and use data from the tool. This was a persistent theme. In Clarke's study, [7] stratification data was prepared in a form that patients could read, and was used as a method of improving health literacy. The **JADE** controlled trial in Hong Kong [1] used a web-based system with a series of risk engines to stratify patients into different risk groups. Doctors could access this patient information with a portal that linked risk profiles to decision support tools and care guidelines following the recommendations of the International Diabetes Federation. GPs in the **Prism** study [11] were encouraged to continually compare their own understandings and expectations of patients' risk scores. A review of predictive risk models [25] in use in the UK warned that engagement of clinicians at the point of implementation was essential: "clinicians need to understand how the predictions made by the model can help them in managing their population with long term conditions".

A German study of risk stratification in primary care argued that acceptance among patients and primary care providers was higher if case finding involved some judgement by the clinicians. Risk stratification helped counter a personal sympathy/aversion element that biased doctor's judgements about which patients to admit to a new program. However, risk stratification on its own lacked an important capacity to judge patients' "willingness and ability to participate" and "manageable care needs" [10].

This factor became a barrier to the take-up of **PARR** in Virtual Wards in Croydon Primary Care Trust in London [15]. GPs resisted the selection of patients purely on the predictive risk model, and even asked to have a right to select who was admitted to treatment. The largest challenge to the use of **PARR** remained a perception that it led to referrals "from a computer".

The only study to attempt a rigorous implementation science framework [33] advocated a knowledge brokering team to develop relationships with users of its **Diabetes Population Risk Tool (DPoRT)**. This Canadian tool draws on publicly available data to develop a population level risk tool and then uses tailored training and customised dissemination strategies to present the model to decision makers. At present, this project is still at the stage of a protocol for a full evaluation.

Other workforce issues included concerns about overloading healthcare providers. The introduction of stratification [7] can lead to quite different patterns of patient flow. Existing systems (and staff) can be overwhelmed without careful planning.

- **Contexts of introduction**

One key to the successful introduction of new instruments in the Basque Country was its positioning within a clearly articulated broader strategy with two-way communication between planners and health care providers [7, 9]. Provider buy-in was necessary from the start. While the technical task of linking primary care, hospital and other data made the implementation of risk stratification feasible it was noted that: "For population stratification to be most useful and practical, other initiatives should be developed in parallel,

such as better integration of health care and social care services, education and training, the creation of new job descriptions, or the re-organisation of clinicians' working patterns and time spent on case management tasks". [28]

Some examples of successful implementation could be characterised as 'top-down'. The Indiana Chronic Disease Management Program [17], based on Medicaid recipients, relied on the active support of the Indiana state government and access to its centralised Medicaid claims data. This program base enabled development and use of the risk stratification tool. Using a single, restricted program also sets some limits. State Medicaid agencies have limited management capacity to create and run disease management programs with a more population or system-level approach.

Other centralised systems have transcended some of these difficulties with more integrated models, drawing across different sectors of care. Kaiser Permanente [6] has provided the most influential model of a closed system that draws on linked data from primary care and hospitalisation to develop sophisticated predictive risk models. The Scottish **SPARRA** risk tool [12] has also developed a more centralised and integrated approach. **SPARRA** uses one central data collection and processing unit. This population-level risk tool is run centrally with information sent out to primary care or through a secure and user-friendly, colour coded online portal. GPs can use the portal to access and use their own data.

A comparison of three English case studies of 'Virtual Wards', a model of integrated primary and social care [13], saw the wider operating environment as the main condition enabling successful implementation of risk stratification tools. These elements included the organisational culture, the existence of multidisciplinary teams and active patient participation.

The Croydon Virtual Wards model was launched in 2006 in a national health policy climate that encouraged this type of intervention and especially the use of predictive tools for case finding. It received strong support at managerial level, from the Primary Care Trust and local medical committee, including access to GP data managed by the Trust, which fed into the **Combined Predictive Model**. The weakness of the Croydon model lay in its detachment from the GPs. The model of case management was one-on-one by a matron, with no role for case management by a multidisciplinary team including GPs. Regular 'mortality and morbidity' meetings were held between the PCT and practice organisations, but GP involvement remained elusive. Community matrons and other community healthcare providers used a common electronic medical record, but these were not available to GPs or hospitals. As a result, the care plans based on risk modelling were based on informal collaboration between matrons and GPs, plans that were often not documented and did not draw directly on risk modelling. There was no portal with which GPs could access data from the risk predictive instrument. In these circumstances, as the program matured there was a steady retreat from multidisciplinary case management back to traditional care.

In contrast, a model in Devon was more rooted in primary care, championed by a GP and only taken up by the Primary Care Trust after his/her advocacy. The Devon model, based on a local variation of the **CPRM**, received good take up in primary care. It also struck some real problems, but these were came from the bureaucratic structures of the local PCT organisation, including perverse financial incentives for hospitals to admit more patients, undermining one of the main objectives of the program.

A third model, in Wandsworth, also had considerable initial support from general practice. Wandsworth used PARR as its risk stratification tool. This choice strengthened GP support, but at the expense of an

effective risk predictive system. In contrast to the whole population approach of the **Combined Predictive Risk Model**, used by Croydon and Devon, the Wandsworth PARR tool throws a smaller net, only looking for patients with a prior hospitalisation. With fewer at-risk patients identified, it relied on GPs for referrals – only a quarter came through the risk prediction tool. As a result, it remained more popular with local GPs, who could refer their difficult-to-manage patients.

- **Data and the tool**

Studies of clinician take-up [16] emphasised the need for reliable, up-to-date data. The Basque Country study [7] [28] added that clinicians wanted to be able to access and use the data independently, with usable information, social as well as strictly medical data, at the group as well as the individual level. However, a New Zealand survey of risk instruments [27] has warned that inclusion of non-needs based social indicators, such as gender, to predict risk may mean some groups are unfairly offered more interventions.

A Valencia study [19], on the use of risk stratification tools within a chronic disease management program (the Sustainable Social and Healthcare Model) drew participants from three local health departments. This program was based primarily on hospital avoidance and made successful use of centralised administrative data to stratify patients, drawing directly from hospital and clinical information systems, rather than the usual telephone or interview methods used with **CARS** and **Pra**.

A regular theme was the need for risk stratification tools and data to be usable in other contexts. The **Framingham Risk Score** [20] was used as a risk stratification tool, but also to educate patients about care options and for guidance on choosing the best care options. The study reported some success in patients deciding to address risk factors (although there was no follow-up on how long this resolution lasted). The **FRS** is based on historical population cohort, whose characteristics and needs differed from contemporary primary care populations. Attempts to modify its formula were found to be 'sub-optimal'.

The evaluation of the implementation of **Prism** [39] found complexity and difficulties in signing up and unforeseen incompatibilities in computer systems were major barriers to early take-up. The **PARR** model [15], which is based on recent hospitalisations, was easier to use, but had limited usefulness for the general population. The more sophisticated **Combined Predictive Risk Model**, which can deal with broader populations, needed to be adapted to local circumstances, which made it more costly and time intensive to implement.

Knutson's 'Predictive Modelling Guide', an operating manual produced for the Medicaid program [23] argued that users (in this case US states) would achieve considerable savings by developing their own predictive models rather than licensing commercial products. A case study of Washington State suggested that this enhanced the ability to customise the instrument, drew – and built upon – knowledge of local population data, and strengthened connections between data managers and care staff. Start-up costs were estimated as higher, but local ability to modify the instrument saved up to an estimated 25% of costs in the longer term. This favourable outcome was dependent on the ability to find and keep staff, including software engineers, health economists and statisticians. Washington State was also helped by 10 years' experience in building a data integration system.

A review of risk predictive models in the United Kingdom [25] sets out the business case for implementing a predictive model. This would include setting a risk score threshold and the desired reduction in hospital

admissions and the cost of the intervention. The key cost factors rest on the availability of data and the expense of obtaining new, necessary data. Privacy and security concerns must be costed, as data must be available in pseudonymous form – raw data or identified data should only be available to clinicians who know the patient. The cost of the algorithm tool itself includes the software on which it is run and the labour and dissemination expenses.

The comparative study of 'Virtual Wards' [13] found that the Devon version of the **CPRM**, which had started with solid foundations in primary care, faced its worst difficulties with issues of data management, especially information governance. Major problems arose in extraction of data from GP systems for predictive modelling and with the system for transferring information back to GPs to give their patients' predictive risk scores. Most obstacles came from data protection and other legislative and administrative safeguards, rather than GP resistance.

The NHS England: Case Finding & Risk Stratification Handbook [24] points to a legal labyrinth of data protection and human rights legislation and the Common Law Duty of Confidentiality. Patient consent and data pseudonymisation (using the encryption of NHS identification numbers) are seen as the two routes through these legal barriers.

- Equity issues

Most issues of equity came from the design of the instrument and other data issues. For example, the Nuffield Trust survey of the use of risk stratification instruments in the English NHS raised privacy issues around data linkage [30].

More targeted 'impactibility' models were discussed because of evidence that they are superior for identifying patients with complex but manageable comorbidities [40]. These models take the results of a more standard predictive model and try to predict the sub-groups of these at-risk patients who are most likely to respond to case management. The Croydon 'Virtual Wards' study [15] rejected this approach on equity grounds, as the measure of likely success is likely to exclude patients with substance abuse, mental illness or other disadvantages.

Assessment

- Successes and failures

The measurement of 'success' is a complex question. The answers to question 1 showed the weakness of the evidence in current research in this area. Risk stratification is only a preliminary step to clinical and other interventions. Those (few) studies which attempted to measure system level outcomes [1] made no attempt to separate the effects of risk prediction and the actual intervention.

An exception to this lack of attention on clinical outcomes was studies that looked at the secondary use of data drawn from risk stratification, especially effects on changing systems of practice. Where clinicians had easy, user-friendly access to data concerning their own patients, there was greater acceptance of risk stratification. This was especially true where the stratified data was linked to clinical guidelines to suggest directions for treatment. The other side of the coin was reports of the use of risk stratification results in patient education.

A second dimension of success was the implementation of the tool itself, regardless of the clinical impact of the broader intervention. Here again, there was a broad distinction between studies of settings and interventions that included the delivery of primary care and those starting from hospital settings, the closed environment of the Kaiser Permanente system or centralised claims data. The latter showed little or no concern with the active support of clinicians [8, 17,19,30]. Every study involving primary care, especially general practice, saw the engagement of clinicians as the key to success. These ranged from studies of risk stratification within primary care [10, 15], through to the more integrated Scottish and Basque health systems [9,12],). These distinctions between drivers of successful implementation crossed system boundaries and were the one generic predictor of successful adoption.

In primary care, active engagement of GPs emerges as a common thread in successful implementation. GPs have been involved in design from the start. More importantly, they have found direct benefits for their patients in access to the results of risk stratification tools PR. This has often taken the form of web-based, user-friendly portals, often linked to evidence-based trusted decision tools offering appropriate guidance for the particular risks faced by a patient. Risk stratification tools are a supplement not a replace of clinical judgement [24].

As seen with question 1, some of the trials currently underway may provide better answers to the broader effects of risk stratification, improving implementation. The **Prism** trial [32] is looking at the costs of implementation and the cost effectiveness of the instrument (using cost per quality-adjusted life year based on changes in patient health outcomes) – questions that no other study in this review has broached. It will measure changes in the profile of the services provided to patients and levels of patient satisfaction. It will also look at broader contexts than those in previous studies: how the **Prism** instrument is understood, communicated and used by the clinicians, managers, local commissioners and policy makers.
The **DPoRT** [33] knowledge translation protocol promises "approaches specifically designed to support the application of tools designed to generate future population-level risk profiles to facilitate decision making".

8 Question 3:

How were these models adjusted or adapted during or after the evaluation to take account of critical enablers and barriers?

Key findings

Changes during implementation or after an evaluation of the use of a risk stratification tool were rarely discussed in the identified studies. Evidence is from descriptive case studies only and therefore weak.

- **In some jurisdictions the predictive accuracy of an 'off-the-shelf' risk stratification tool was found wanting when applied in local contexts. Tools were adapted using new locally relevant indicators and validated locally**

- **Most tools are re-calibrated on a regular basis (every 2–4 years)**

- **In some jurisdictions, the introduction of training and information packages for clinicians increased engagement, with and acceptance of, a risk stratification tool**

- **In some jurisdictions, the implementation of the tool was changed to formally include clinical judgement in the decision making process, either at the point of decision to treat, or by establishing new criteria for inclusion/exclusion through surveying clinicians' opinions**

- **The mechanism through which tool outputs are distributed to clinicians has evolved over time. In early approaches data was sent to clinicians via email or mail, resulting in a time-lag and the impression of out-of-date data. More recently clinicians can access tool outputs through secure web-based user interfaces**

- **The frequency at which the risk stratification algorithms tend to be run has evolved from periodic (six-monthly, monthly) to continual.**

Adaptations and adjustments

An early study of the Welsh **Prism** Chronic Care Demonstration project [11] reported that first responses to the tool were "mixed" but found that user involvement (again from GPs) in developing improved versions of the tool helped reverse initial failures. Resistance from GPs to the risk modelling associated with the Croydon 'Virtual Ward' was seen as at least partly due to the novelty of the predictive risk model as a concept [15]. The King's Fund led a series of presentations to GPs, setting out the evidence base for predictive modelling and explaining its advantages in accuracy over clinical opinion. This does not seem to have been very persuasive as it then took "months" for all relevant parties to reach agreement.

Other studies continued the theme of clinician engagement. The Israeli **ACG** model [18] has had problems with an instrument that included excessive proportions of very high-risk patients. This is being resolved with a panel of six doctors who make exclusions on clinical grounds from those identified by the instrument. The German primary care-based study [10] argued that problems of excessively rigid risk predictive algorithms could be resolved by bringing the implementation of the tool closer to needs and values of final users. It reiterated the message common to all the primary care based studies: that clinicians need to be involved in development of risk stratification tools from the start.

There were several reports of managing change while improving tools or adapting tools used in other jurisdictions. For example, in the Nairn district in Scotland the **Nairn Case finder** [2] was implemented with particular features to improve on aspects of the related **SPARRA** tool. SPARRA, sent updates six-monthly and was therefore considered to be based on potentially old data; it was (at the time) based on hospital data as inputs. The Nairn Case Finder was run on a monthly basis centrally in the practice to enable communication with the anticipatory care team and was changed to include GP data.

Surveys of instruments, such as Knutson's 'Predictive Modelling Guide' for Medicaid [23] argue for continuous improvement of data. The risk score should always be seen as a starting point and must be supplemented by a continuous process of using non-traditional data – functional status, social context and health behaviours and attitudes. This involves "continuous and targeted data mining". The Indiana Chronic Disease Program [17] gradually broadened the basis of its scoring of risk. It started with a cost-effectiveness model, using Medicaid claims data to target high intensity intervention to those participants most in need. The study reported that enhanced stratification algorithms were being considered to broaden the types of information used in calculating risk. This would include more self-reported data collected by telephone from program participants, including self-rated health, expected health service utilisation in the next year and whether a participant names an individual doctor as their primary source of care.

9 Question 4:

What key learnings are to be derived from implementing strategies or approaches to risk stratification, from a system wide perspective?

Despite the lack of strong studies – and the complete dearth of Australian evaluations of risk predictive instruments – some learning points can be extracted that are relevant to the NSW context.

- A state-wide approach to risk stratification will need to decide on whether to purchase a ready-made commercial risk stratification tool, or develop a new one. The literature demonstrates some of the benefits of starting afresh, especially in developing around local data sources and problems. The pitfalls are also clear, mainly around workforce and cost

- The design of a new tool or adaptation of a ready-made one will depend on ready availability of relevant linked data, minimal expenditures and labour to link incompatible systems

- The risk stratification tools that met greatest acceptance and fewer teething problems were embedded in clearly explained, broader disease management and care integration strategies

- The risk stratification tools that won swiftest support from clinicians were designed with user-friendly portals so that doctors, other health practitioners and wherever possible, patients, could access useful information, often linked to decision-aids relevant to the patient's risk group

- Data protection and privacy issues need to be sorted out very early

- Health care practitioners, especially in primary care, were more likely to embrace new methods of case finding if they were consulted at every stage. If they could see a clear benefit to their own patients, they were much more prepared to make some of the changes in practice required and less likely to see risk stratification tools as an attack on clinical judgement

- Considering the lack of publicly available information on the implementation of risk stratification tools in real-world settings, any adoption of such an approach in NSW should include rigorous evaluation.

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11 Appendices

Appendix 1: Search terms adapted to included databases

Medline via OvidSP

Risk stratificat*.tw OR Risk profil*.tw OR Population profil*.tw OR Population segment*.tw OR Predictive risk.tw OR (Predict* adj3 model).tw OR Risk adj4 Predict*.tw OR (Risk adj3 Population*).tw OR (Risk adj3 model*).tw OR Stratificat* adj3 strateg*(.tw) AND Health services [MeSH] OR Managed Care Programs [MeSH] OR Primary Care (or Primary Health Care [MeSH]) OR Aged Care.mp OR Hospital [MeSH] OR Health System.mp OR Population health.mp AND Models.tw OR Tools.tw OR Program.tw OR System.tw
Filter by year: 2000–2015

Embase

(('health services' AND [2000–2015]/py) OR (managed AND care AND [2000–2015]/py) OR ('primary care' AND [2000–2015]/py) OR (aged AND care AND [2000–2015]/py) OR ('hospital' AND [2000–2015]/py) OR ('health system' AND [2000–2015]/py) OR ('population health' AND [2000–2015]/py)) AND (('models' AND [2000–2015]/py) OR (tools AND [2000–2015]/py) OR ('program' AND [2000–2015]/py) OR ('system' AND [2000–2015]/py)) AND 'population risk'/exp

CINAHL

"Risk stratificat*" OR (MM "Risk Assessment") "Risk profil*." "Population profil*." ""Population profil*."" OR "Stratificat* strateg*" AND (MM "Health Services for the Aged") OR (MH "Health Services+") OR "Health services" OR (MH "Managed Care Programs+") OR "Managed Care" OR (MH "Multidisciplinary Care Team+") OR (MH "Health Care Delivery, Integrated") OR "Primary Care" OR (MH "Primary Health Care") "Hospital" OR (MH "Health Facilities+") AND "model*" "tool*" "program*" OR"System"
Filter by year: 2000–2015

Scopus

(TITLE-ABS-KEY ("risk stratific*") OR TITLE-ABS-KEY ("risk predict*") OR TITLE-ABS-KEY ("populat* risk") AND TITLE-ABS-KEY ("health servic*") OR TITLE-ABS-KEY ("health system*") OR TITLE-ABS-KEY (hospitalis*) AND TITLE-ABS-KEY (model*) OR TITLE-ABS-KEY (system*) OR TITLE-ABS-KEY (tool*) OR TITLE-ABS-KEY (program*) AND TITLE-ABS-KEY (populat*)) AND SUBAREA (mult OR medi OR nurs OR vete OR dent OR heal) AND PUBYEAR > 1999 AND PUBYEAR < 2016 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBAREA , "MEDI") OR LIMIT-TO (SUBAREA , "SOCI") OR LIMIT-TO (SUBAREA , "NURS") OR LIMIT-TO (SUBAREA , "HEAL") OR LIMIT-TO (SUBAREA , "ECON") OR LIMIT-TO (SUBAREA , "ARTS") OR LIMIT-TO (SUBAREA , "BUSI"))

Cochrane library

"risk stratification" in Title, Abstract, Keywords or "risk stratification model" in Title, Abstract, Keywords and "health care" in Title, Abstract, Keywords or "health care facilities" in Title, Abstract, Keywords or "health care delivery" in Title, Abstract, Keywords in Other Reviews
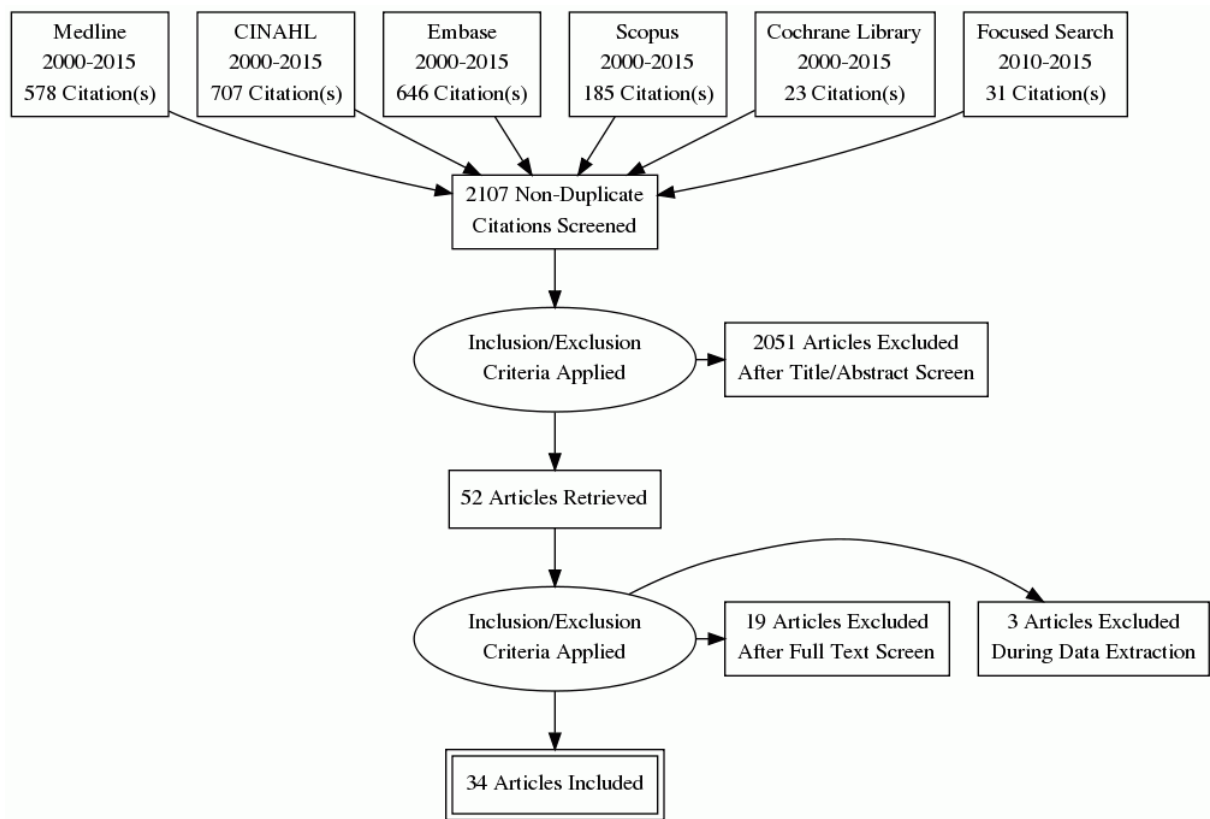
Appendix 3: Table of included papers

#	Author (year)	Setting	Risk stratification tool(s) applied	Evidence type – design (NHMRC level of evidence)	Key results / factors influencing implementation
1	Arce, De Ormijana, Orueta, et al. (2014)	PC practices, Basque Health Service, Spain	Johns Hopkins University Adjusted Clinical Groups	Qualitative study – purposive sample of 12 GPs and 11 PC nurses in PC centres that adopted tool participated in focus groups. (n/a)	Factors influencing implementation: Clinicians' views on the tool and on the implementation process are closely interlinked and influence each other. Enablers and barriers identified related to: characteristics of adopters; clinicians values; degree to which risk stratification is part of a broader strategy with good communication; independence of end users to manage information; up-to-date data; communication strategy; practice settings; workload; reliability of the tool; ease of use; equity risks of targeting; resistance to change to a population approach.
2	Badenbroek, Stol, Nielen et al (2014)	PC practices, The Netherlands	Finnish Diabetes Risk Score (FINDRISC)	Protocol, evaluation with randomised stepped-wedge waiting list control group – patients in a representative sample of 40 PC practices risk stratified and offered a care management package. (II)	Results expected 2016.
3	Baker, Leak, Ritchie, et al. (2012)	PC practices, Nairn, Scotland, UK	Nairn Case Finder	Evaluation with concurrent cohort control – 96 patients each from two similar PC practices were matched for age, sex, multiple morbidity indexes, and secondary care outpatient and inpatient activity. Patients from one practice received a managed care plan, the other acted as control. (III-2)	Mortality rates in the two cohorts were similar, but the hospital bed days used in the last three months of life were significantly lower for the decedents with an Anticipatory Care Plan. Factors influencing implementation: use if primary care vs. hospital data for populating tool, time delay between data provision and front line use of tool.
4	Boult, Boult, Morishita et al. (2001)	PC practices, Ramsey County, Minnesota, USA	Pra instrument	Evaluation with randomised control – Medicare beneficiaries age 70 and older were stratified using Pra. Baseline measurements were obtained for all high risk respondents (Pra >0.4) (N=570). Patients were matched according to Pra stratification block and randomised. Control patients received care their physician deemed appropriate after receiving notification of risk. Intervention group patients received an interdisciplinary care package. (II)	Intention-to-treat analysis showed that participants receiving the care package were significantly less likely than the controls to lose functional ability (adjusted odds ratio (aOR) 0.67, 95% confidence interval (CI) 0.47–0.99), to experience increased health-related restrictions in their daily activities (aOR 0.60, 95% CI 0.37–0.96), to have possible depression (aOR 0.44, 95% CI 0.20–0.94), or to use home healthcare services (aOR 0.60, 95% CI 0.37–0.92) during the 12 to 18 months after randomisation. Mortality, use of most health services, and total Medicare payments did not differ significantly between the two groups. Factors influencing implementation: Instrument can be used off the shelf; paper-based, self-administered tool.

#	Author (year)	Setting	Risk stratification tool(s) applied	Evidence type – design (NHMRC level of evidence)	Key results / factors influencing implementation
5	Boult, Leff, Boyd et al. (2013)	Eight community-based PC practices in Baltimore, MD and Washington DC, USA	Hierarchical Condition Category (HCC)	Evaluation with randomised cluster control. Patients were selected for initial screening according to age (>65) and type of insurance coverage. Patients were potentially eligible if their HCC risk ratios were in the highest quartile of the population of same age category patients covered by their health care insurer. Patients were randomised by cluster (i.e., by team of physicians). 419 patients received usual care and 485 received the 'Guided Care' package comprising eight nurse led services. (II)	In intention-to-treat analyses, Guided Care did not significantly improve participants' functional health, but it was associated with significantly higher participant ratings of the quality of care (difference= 0.27), (95% CI=0.08–0.45) and 29% lower use of home care (95 % CI=3–48%). Factors influencing implementation: systematic identification and intensive care management (including frequent face-to-face contact) of high-risk patients; primary care physicians collaborating with on-site registered nurses and other staff (all working in redefined roles "at the tops of their licences"); health information technology that facilitates coordinated care.
6	Clark, Snyder, Meek, et al. (2001)	Managed Care Organisation, Las Vegas, USA	Purposefully developed tool based on the American Diabetes Association Clinical Practice	Evaluation with a concurrent cohort control. Two PC clinics each enrolled 370 patients (N=740) who received the intervention. Data from 623 members at a third clinic acted as control. Patients were stratified into high-, moderate-, or low-risk groups within disease categories. Interventions were based on previously agreed-upon care plans after approval from the primary care physician. Complete data were available from 193 patients who completed the program to 12 months. (III-2)	The number of patients in the low-risk category (HbA$_{1c}$,7%) increased by 51.1%. A total of 97.4% of patients with an HbA$_{1c}$ >8% at baseline had a change in treatment regimen. Patients at the highest risk for coronary heart disease (LDL 130 mg/dL) decreased from 25.4% at baseline to 20.2%. Patients with a blood pressure, 130/85 mmHg increased from 23.8% to 44.6%. Patients and providers expressed increases in satisfaction with the program. Factors influencing implementation: Patients educated and informed of their data and risk status (to prepare for PC visit); close involvement of PC providers to assure standards and recommended actions were consistent with practitioners' views; altered patient flow; a system that collated the data and presented it in a format that was immediately understandable by (and useful to) the patient and the provider; automated clinical decision support and reminder lists for a team care coordinator.
7	Cohen, Flaks-Manov, Low et al. (2015)	Clalit Health Services, Israel	Johns Hopkins University Adjusted Clinical Groups	Descriptive case study – the Clalit Health Service implemented a system whereby the selection of patients for inclusion in a managed care program combined risk stratification through the tool with a set of additional exclusion criteria created through a survey of physicians eliciting the clinical basis on which they currently identify high-risk patients. (n/a)	Factors influencing implementation: A combined predictive risk tool-clinical input approach to patient selection for care management; accounting for impactibility, predictive accuracy, and resource capacity.

#	Author (year)	Setting	Risk stratification tool(s) applied	Evidence type – design (NHMRC level of evidence)	Key results / factors influencing implementation
8	de Manuel, Keenoy, Mora et al. (2014)	PC services for aged in Europe	Various	Protocol, comparative case studies. Work packages include: development of a standard for appraising stratification tools; analysis of the feasibility of using tools in healthcare including barriers and facilitators; impact of stratification tools on structure and processes of healthcare organisations, on health services resources, management and clinical practice. (n/a)	Expected in 2015.
9	Dhalla, O'Brien, Morra et al. (2014)	Toronto Central Local Health Integration (Hospital) Network, Toronto, Canada	LACE	Evaluation with randomised control – high risk patients identified using the LACE tool administered at discharge in four hospitals were randomly allocated to either admission to a 'Virtual Ward' (N=963) or usual care (N=960). (II)	There were no statistically significant differences between groups in hospital readmission or death at 30 or 90 days, six months, or one year. There were no statistically significant interactions to indicate that the Virtual Ward model of care was more or less effective. Factors influencing implementation: Hospital led and implemented tools with no integration with primary care services.
10	Dixon, Lewis, Rosen et al (2004)	Managed Care Organisations in the USA	Various	Review of tools – the approaches of five MCOs to the care of chronic disease are analysed in terms of 1) the wider environment in which they operated – for example, the use of market incentive; 2) their organisational domain – including the relationship between healthcare purchasers and providers; 3) clinical process – such as the disease management programmes in place. (n/a)	Factors influencing implementation: required investment in computer software; market pressures to reduce hospital costs for high risk patients; strength of the business model to identify incentives to implement tool; quality of data for linkage.

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11	Doñate-Martínez, Garces Ferrer, Rodenas Rigla, et al. (2014)	Valencian Healthcare System, Spain	Pra and Community Assessment Risk Screen (CARS)	Descriptive case study – Pra and CARS were used to detect patients at risk of hospital readmission in a sample of 500 patients aged >65. Administrative data were to populate the tools which, when purchased off-the-shelf need to be populated manually with a patient survey. Both tools implemented this way were found to have an acceptable level of accuracy in the prediction of hospital admissions. (n/a)	Pra and CARS could be adapted for automatised risk stratification using a primary health administrative dataset. Factors influencing implementation: Availability of high quality linked data sets in primary care, hospital care and pharmaceutical prescriptions; ease of use for patients and practitioners.
12	Freund, Wensing, Geissler et al. (2012)	PC Practices, Munich, Germany	Case Smart Suite Germany (CSSG)	Qualitative study – 12 PC physicians first selected 30 patients for inclusion in a managed care program using clinical judgement and then again using the CSSG tool. Semi-structured interviews were used to elicit how the PC physicians experienced using CSSG.	Overall, PCPs rated the approach useful for identifying patients likely to benefit from care management. However, they were concerned about time lags between data analysis and patient recruitment/adherence. Factors influencing implementation: Acceptance may increase among both patients and PCPs if case finding involves judgement by PCPs.
13	Georghiou, Blunt, Stevenson et al. (2011)	UK and USA	Various	Review of tools – reviews uses, limitations, and emerging developments of risk stratification tools. (n/a)	Factors influencing implementation: Privacy protection; quality of administrative datasets; linkages to resource allocation.
14	Hutchings, Evans, Fitzsimmons et al. (2013)	Wales, UK	Prism	Protocol, evaluation with cluster randomised stepped wedge design using mixed-methods. Primary care practices will be randomly selected to receive Prism and different time points thereafter use Prism with clinical and technical support. Costs, processes of care, satisfaction and outcomes at baseline, six and 18 months, using routine data and postal questionnaires will be assessed. Focus groups and interviews will be undertaken to understand how Prism is perceived and adopted by practitioners and policy makers. (II)	Results expected in 2015.

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15	Jiao, Fung, Wong et al. (2014)	GP practices, Hong Kong	Joint Asia Diabetes Evaluation Risk Engine (JADE)	Evaluation with matched control design – 1248 patients with diabetes were randomly selected for participation. Participants were matched by age, sex, and HbA_{1c} level at baseline with a further 1248 patients as the control group. Intervention were risk stratified as 'very high', 'high', 'medium' and 'low' risk. Different care management strategies) were applied according to each patient's profile. (III-1)	The intervention group had lower cardiovascular events incidence (1.21% vs. 2.89%, P=0.003), and net decrease in HbA_{1c} (−0.20%, P<0.01), SBP (−3.62 mmHg, P<0.01) and 10-year cardiovascular disease (CVD) risks (total CVD risk, −2.06%, P< 0.01; coronary heart disease (CHD) risk, −1.43%, P<0.01; stroke risk, −0.71%, P<0.01). After adjusting for confounding variables, the significance remained for HbA_{1c}, predicted CHD and stroke risks. Factors influencing implementation: Risk stratification directly linked to recommendations for care; user interface to allow direct access to practitioners and which includes decision support.
16	Jones, Shah, Bruce et al. (2011)	Community based PC practices, Pennsylvania, USA	Framingham Risk Score	Descriptive case study – patient-reported data were obtained via a touchscreen device-administered questionnaire in PC practices practice and automatically combined with an electronic health record (EHR) data to calculate risk. Higher-risk patients viewed an interactive web-based tool and chose treatment options to modify risk factors. A real-time simulation indicated directly to patients their expected outcomes when the treatment option is followed. (n/a)	Following a trial period during which 1068 patients used the device, the system was considered feasible for full implementation. The Framingham Risk Score was modified for final use. Factors influencing implementation: Stratification of risk within the primary care setting; limited availability of risk stratification tools in a format that is amenable for direct use by GPs together with patients in shared decision making; ability to link off-the-shelf tools with GP records.
17	Katz, Holmes, Stump et al. (2009)	Indiana Chronic Disease Management Program, USA	Purposefully developed tool.	Evaluation – multiple baseline study. The tool was used to stratify participants to highest 20%/lowest 80% risk and assign a care package accordingly. Program was rolled out in three regions of the state (Central Indiana in July 2003, Northern in July 2004 and South October 2004). During which 14 repeated cohorts of Medicaid members were drawn over a period of 3.5 years and the trends in claims were evaluated using a repeated measures model. (III-2)	There was a flattening of cost trends between the pre- and post-intervention initiation periods and these remained flat in the final year of follow-up. Factors influencing implementation: Targeting specific diseases; centralised uniform dataset capturing whole population; provision of decision-support with tool; use of risk stratification tool to determine composition of care package.

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18	Kingston (2010)	NHS Wales	Prism	Qualitative study – focus groups and interviews with staff in 13 GP practices taking part in the demonstrator testing of Prism including locality planning coordinators and GP leads. (n/a)	Clinicians found that most of the highest-risk patients identified through the tool were known to them as high-risk patients. However, there were examples of patients whose risk score was much higher or lower than they expected. For those higher risk patients, the data provided impetus to further investigate these patients. Factors influencing implementation: remote access to anonymised or raw data; privacy and data governance; separation of service planners to patients; complexity/simplicity of the sign up process to gain access to the tool; provision for end user feedback to improve tool; end user friendly interface; integration of social care data when tool is to be used for care integration.
19	Knutson, Bella, Llanos. (2009)	USA (Medicaid)	Various	Implementation Guide – guides key factors for consideration when purchasing and implementing off-the-shelf risk stratification tools. (n/a)	Factors influencing implementation: Design and reporting logic; correct calibration in context; frequency of calibration; data requirements and monitoring; time-lag specifications; costs.
20	Lewis (2010)	Croydon Primary Care Trust, UK	Combined Predictive Risk Model	Descriptive case study – whole of population under the jurisdiction of the PCT were risk stratified. "Virtual Wards" were established along geographical lines of density of high-risk individuals. Patients registered with one of the participating general practices were identified using the tool as high risk and admitted to a 'Virtual Ward' receiving managed care. The 'Virtual Ward' team received an alert if the patients dropped off the high-risk list and may be discharged. (n/a)	Factors influencing implementation: Data requirements, data security and pseudonymous data; provision of a user-interface as part of an off-the-shelf tool; initial costs of establishing tool; frequency of recalibration; governance and responsibility for commissioning tools; setting a business case for adoption of tool; engagement of local clinicians at the point of implementation; linking use of tool to a wider population management strategy.
21	Lewis, Curry, Bardley, (2011)	United Kingdom	Various	Implementation guide – analyses a range of factors to consider at the commissioning stage if tool implementation. (n/a)	Factors influencing implementation: opening of market to competition (decommissioning of public models); availability of high quality data; location where tool will be run (in PC practice, level of primary care organisation; regional health authority); tools set up costs.
22	Lewis, Vaithianathan, Wright (2013)	Croydon, Devon and Wandsworth PCTs in England, UK	Combined Predictive Risk Model, PARR, Devon Predictive Model	Comparative case studies (descriptive) – compares three uses of risk stratification tools in PCTs, the Combined Predictive Risk Model in Croydon; an adapted version with a new interface in Devon and the PARR model in Wandsworth. The study traced enablers and barriers to successful implementation. (n/a)	The type of tool used was slightly different in each case presented. The nature of the Virtual Ward program differed in terms of composition of the multidisciplinary team, leading 'Virtual Ward' staff (community matrons, ward clerks, ward GP) and timing of implementation. Factors influencing implementation: Funder of the model and relationship to commissioning agency; operating environment; organisational culture; culture of integration/GP involvement; data sharing; program champions.

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23	Lewis, Wright, Vaithianathan (2012)	Croydon, Devon, Wandsworth and Somerset PCTs, Toronto, Canada and New York, USE	PARR, Combined Predictive Model, Devon Predictive Model, LACE, purposefully developed tool based on Medicaid data	Comparative case studies (descriptive) – descriptive accounts of how six managed care schemes vary in terms of the use (or non-use) or risk stratification and composition of care packages. (n/a)	Factors influencing implementation: Mobility of population/ability to reach patients; use of case managers from appropriate sector; using impactibility models to identify high priority patients.
24	National Health Service England (2015)	England, UK	Various	Implementation guide – summarised current requirements for data governance, privacy, and choosing a risk stratification tool in the free market. (n/a)	Factors influencing implementation: Fair processes of data; information governance (changing regulations and requirements; pseudonymisation); stratifying whole vs. part population; end user friendly interface; supplementing risk stratification with self-assessment tools.
25	National Health Service Scotland (2011)	Scotland, UK	SPARRA	Qualitative study – 25 end users of SPARRA at Community Health Partnerships (CHPs), Health Boards, and PCPs completed a survey asking 1) to whom SPARRA data is forwarded; 2) local modifications to the output; 3) local additions to the output; 4) which data sharing protocols in place; 5) what are the local uses of SPARRA data and 6) suggested additional data/information to be included in the SPARRA output. (n/a)	Patterns of dissemination were variable and complex; a small risk of duplication was identified as well as a risk that data does not always reach intended end users. A range of approaches to data security were taken by SPARRA end users. Prescribing data was identified as highly desirable to augment the SPARRA algorithm. Factors influencing implementation: data security, time-lag between data entry, running tool and reaching end users; institutionalised feedback from end users to inform improvements in tool.
26	Nuno-Solinis (2013)	Spain	Various	Review of tools – outlines basic concepts of predictive modelling, describe some of the models that have been developed internationally with descriptive case studies from the Spanish National Health Service.	Factors influencing implementation: Ability to link primary care and hospital datasets; inclusion of professionals and patients in implementation design; implementing risk stratification as part of a wider integrated health strategy; training in use of tool, patient identification by name and surname; end user friendly interface; usable information provided at both the individual and group level.
27	Panattoni, Vaithianathan, Ashton et al. (2011)	New Zealand and Australia	Various	Review of tools – reviews the current knowledge about PRMs and explores some of the issues surrounding the potential introduction of risk stratification tools to a public health system with the examples of New Zealand and Australia. (n/a)	Factors influencing implementation: Confidence in accuracy of algorithm; data protection (e.g. pseudonymous keys); using non-needs-based indicators (e.g. gender) to predict risk might mean certain groups are unfairly offered more interventions.

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28	Purdy (2010)	United Kingdom	Various	Review of tools – reviews current knowledge on at risk populations, viable risk stratification tools, and feasible linked interventions. (n/a)	Factors influencing implementation: Availability of data on individual patients; interaction of linked interventions with the particular social context; ability to use both PC and hospital data.
29	Rosella, Peirson, Bornbaum et al. (2014)	Ontario and Manitoba, Canada	Diabetes Population Risk Tool (DPoRT)	Protocol, qualitative evaluation – interviews, observer notes and surveys will be used to identity factors that facilitate uptake and overcome barriers to the use of the tool as intended though the application of a Knowledge-to-Action framework. (n/a)	Results expected in 2015.
30	Rosenman, Holmes, Ackermann (2006)	Indiana Chronic Disease Management Program	Purposefully developed tool	Descriptive case study – describes the implementation of the purposefully built risk stratification tool in the Indiana Chronic Disease Management Program.	Factors influencing implementation: Frequency of running tool; mechanism of distributing results; adapting own algorithm or user-interface; commissioning or partnering with vendor of the tool; centralised patient data; validating risk stratification tool results with patient surveys/clinical assessment; supportive policy environment.
31	Smallcombe, Burge-Jones, PRISMATIC Study team et al. (2013)	Wales, UK	Prism	Implementation guide – describes how to navigate online Prism interface, to register for use, and ensure correct interpretation of tool results for action. (n/a)	Factors influencing implementation: Rules for granting access; end user friendly interface; training for end users; safeguarding against misuse or misinterpretation.
32	Scottish Government Health Delivery Directorate (2010)	Scotland, UK	SPARRA	Implementation guide – outlines what end users can expect when receiving notification of patient risk that have been established through use of tool as well as how to register; clean and utilise data. (n/a)	Factors influencing implementation: One central data collection and processing unit; risk tool run for whole population centrally with information sent to primary carers regularly/or can be accessed through a secure online portal; GPs able to clean and adapt data once received; user-friendly interface (e.g. colour coding); connecting use of tool with a program of managed care
33	Tuso, Huynh, Garofalo (2013)	Kaiser Permanente Southern California	LACE	Evaluation – interrupted time series design. Patients were stratified into low- (LACE score 0-6), medium- (score 7-10) and high- (score 8 -11) risk categories. Different bundles of care were offered to patients accordingly. The program was implemented in all 13 KPSC medical centres discharging approximately 40,000 Medicare risk patients each year during in the first quarter of 2012. (III-3)	Among Medicare risk patients the observed over-expected admissions ratio reduced from approximately 1.0 – 0.8 between December 2010 to November 2012. During the same period readmission rates decreased from 12.8% to 11%, respectively. Factors influencing implementation: Single EMR for all patients; linking hospital and primary care in risk stratification and care.

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34	Zachariadou, Stoffers, Christophi et al. (2008)	Cyprus	SCORE	Descriptive case study – the tool was applied to risk stratify 1011 patients with diagnosis type two diabetes mellitus hypertension or hyperlipidaemia living in Cyprus. The results of the stratification were used to assess the quality of care for patients with these conditions in the country and inform new care policy decisions.	Implementation of SCORE was able to uncover under-treatment of patients with cardiovascular risk factors as well as under prescription of antihypertensive drugs, LLD and aspirin for high-risk groups. Factors influencing implementation: Quality of documentation of clinical information; training of end users.