

# Towards an Architecture for Quality Audit Reporting to Improve Hypertension Management

Thusitha Mabotuwana<sup>1</sup>, Jim Warren<sup>1,2</sup>, Rekha Gaikwad<sup>2</sup>, John Kenelly<sup>3</sup>, Timothy Kenealy<sup>3</sup>

<sup>1</sup>Department of Computer Science

<sup>2</sup>Section for Epidemiology and Biostatistics, School of Population Health

<sup>3</sup>Department of General Practice, School of Population Health

The University of Auckland

Private Bag 92019, Auckland, New Zealand

thusitha@cs.auckland.ac.nz

## Abstract

This paper illustrates an iterative, data-mining based approach to create a set of specific criteria (or quality indicators) for quality audit reporting from Patient Management System (PMS) data in the context of hypertension management. It represents an initial phase of research towards developing an architecture that can be used to easily specify various quality auditing criteria to support process improvement in chronic disease management. To inform our architectural design requirements we have developed a range of specific quality indicators with the assistance of an expert panel consisting of clinical staff from a general practice in Auckland, New Zealand. These criteria have been formulated into a Quality Audit Report (QAR) laid out under three broad categories of criteria: descriptive, supportive, and cautionary. A key aspect of the criteria we have developed is the incorporation of various temporal issues directly related to the successful management of chronic illness – hypertension in particular, and its comorbidities. We are approaching the phase of having clinicians assess a sample of patients, blind to the standing of the patients with respect to the cautionary QAR criteria, to assess the sensitivity and specificity of our inferences from the PMS data.

*Keywords:* Chronic disease management, clinical audit, data mining, hypertension, quality assurance, quality indicators.

## 1 Introduction

The widespread use of computers in the healthcare industry together with the use of an electronic medical record (EMR) has certainly had a positive influence in systematically storing patient information. However, effective use of this vast amount of information to produce globally acceptable clinical indicators for

quality measurement and quality improvement of general practice is arguably still at its infancy. Various attempts made to date to improve clinical outcomes include clinical decision support systems, reminder systems, audit reports, increasing practitioner familiarity with clinical practice guidelines (CPGs), financial incentives for compliance with CPGs and so on.

The aim of our current research is to take advantage of the vast amount of prescribing data stored in general practice Patient Management Systems (PMS) for clinical audit reporting. It has been reported that general practices in New Zealand have a near 100% computerisation rate with 89.7% of general practitioners (GPs) using a PMS for prescriptions (Didham et al. 2004). Stored data in these electronic patient record systems is considered to be of high quality as a record of prescribing (have high sensitivity) (Thiru, Hassey and Sullivan 2003) giving a suitable basis for quality assurance and clinical audit reporting. We use the ideas from (Baker et al. 2002) to define clinical audit as the process of quality improvement that seeks to improve patient care and outcomes through systematic review of care against explicit criteria and the implementation of change.

Work presented here is a stepping stone towards our long term goal where we intend to develop an architecture to support the formulation of various criteria for process improvement decision support (either for interactive alerts or for clinical audit reporting). We expand on our previous work (Gaikwad, Warren and Kenealy 2007) to describe the new methodology we have used together with the various auditing criteria which represent the nature of clinical concerns to be accounted for in the final architecture. We have had several discussions with an expert panel of currently practising physicians to identify key requirements from a practical perspective instead of trying to formally specify potential auditing criteria according to a selected CPG. We believe that there will be a significant overlap between the criteria specified by the clinicians during our sessions and those set forth in a selected NZ CPG in our domain of interest. Here we describe our approach towards implementing the identified requirements of clinicians, using a data mining approach, and then discuss how this work will be used to devise an architecture to easily (possibly graphically) specify auditing and/or

alerting criteria using various domain specific abstract concepts.

The main clinical domain we are currently interested in is *chronic* disease management, especially management of hypertension. This is mainly due to the globally growing need for better management of hypertension to control the ever-increasing demands for clinical resources and also to minimise related healthcare costs. Moreover, chronic disease management introduces technical challenges associated with temporal reasoning, such as problems of computation on time intervals and their relationships. Developing solutions that address these temporal reasoning challenges is the main technical focus of this paper.

This paper is organised as follows. In Section 2 an introduction to the problem domain is given along with supporting reasoning for our data mining approach. Section 3 presents the methodology we have used while Section 4 presents our results and details out the iterative development process of the auditing criteria. Finally in Section 5, a discussion on our current research and future directions are presented.

## 2 Background

Despite the lack of a universally agreed standard for *quality of patient care*, the medical community in general accepts that following well developed CPGs improves quality of care received by patients along with the many other benefits they provide and there is some research based evidence (Grimshaw and Russell 1993, Tunis et al. 1994) to support this statement. A widely used definition in the published literature for a CPG is by the American Institute of Medicine, which defines a CPG as “systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances” (Field and Lohr 1992). A multitude of CPGs have been developed by various national and international organisations mainly since the early 90s, but however active use of these CPGs within the day-to-day practice environment is yet to fully evolve.

CPGs have been developed by various organisations for many chronic conditions as well, such as hypertension, diabetes, coronary artery disease (CAD), hyperlipidemia, stroke, osteoporosis, heart failure (HF), chronic kidney disease, chronic renal failure (CRF) and chronic obstructive pulmonary disease (COPD) to name a few. However many researchers have reported that general practitioner (GP) adherence to a particular guideline is considerably low. Recent claims by Rea et al (Rea et al. 2007) that in New Zealand chronic conditions is the leading cause for hospitalisation further indicates that patients with chronic illness are not managed as well as they should be. They further report that chronic conditions account for 70% of health expenditure and for 80% of all deaths.

Given the gravity of chronic conditions, it is not surprising that efforts have been made in the past to

improve the management of chronic illness. Despite many research projects that have been tried out in real clinical environments as field trials, only a very few have been used on a large scale. Confining the discussion to our main domain of interest, ATHENA decision support system (DSS) (Goldstein et al. 2000) and PRODIGY (**P**rescribing **R**ationally with **D**ecision-Support in **G**eneral Practice Study) (Johnson et al. 2000) are arguably the most well known systems used for improved hypertension management.

ATHENA DSS has two main components, a Protégé knowledge base that models the Sixth Report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC6) (1997) hypertension guideline and a guideline interpreter capable of creating patient specific recommendations based on patient data that are consistent with the knowledge base. It provides recommendations to add, change dose, substitute or delete drugs depending on level of patient blood pressure (BP) control while taking comorbid conditions, compelling indications, possible indications, various clinical concerns and contraindications into account (Goldstein et al. 2000). The system also has some reasoning capability where partial or full deviation from the guideline recommendations for a given scenario may be considered legitimate, provided that clinician intention was still to adhere to the guideline’s primary message (Chan et al. 2004).

PRODIGY is a prescribing decision-support tool that encourages evidence-based cost-effective GP prescribing and was a project that was implemented on a national scale in the UK. Implementations of PRODIGY were rolled out to GPs nationwide in three main iterations (or phases). Experience with phase II proved PRODIGY to be technically competent at acute disease management for advice, shared decision making and prescribing, but representation of guidelines for chronic diseases was judged inadequate (Johnson et al. 2000). PRODIGY Phase III was initiated to develop a system of guidance for chronic disease management in primary care and to overcome the issues encountered with phases I and II. However the use of *scenarios* to provide easy access (also termed *entry points*) to place a patient with chronic illness within the appropriate guideline model are high level viewpoints of patient states. These states are not adequately integrated into detailed patient specific conditions which lie at the heart of chronic illness (unlike acute illness), such as past treatments, therapeutic history, efficiency, effectiveness, tolerance and so on.

An underlying factor common to ATHENA, PRODIGY and most other decision support tools is that they all attempt to computerise relevant CPGs and let the GP prescribe according to the system recommendations, hence using effectively a knowledge engineering approach. Although almost all the systems do have the capacity to let the GPs override the system recommendations and some have critiquing modes where the system interrupts only

when critical alerts need to be made, we take the stance that auditing general practice with specific criteria will be highly (or possibly even more) beneficial for the management of patients with chronic illness. This is further backed by the complexities and difficulties involved with chronic illness where various temporal reasoning mechanisms are required (Warren et al. 2007) and other associated problems reported during PRODIGY phase II implementation (Johnson et al. 2000).

### 3 Methodology

Our approach is mainly a data mining and/or knowledge discovery one as opposed to a knowledge engineering approach. That is, we are not attempting to construct a comprehensive decision support tool that encompasses all the advisories of a CPG. Rather, we iteratively present and explore patterns in antihypertensive prescribing data with the intention of discovering opportunities for the practice to improve the management of chronic illness in their population.

Work presented here involved collaboration with a general practice in a metropolitan area in Auckland, New Zealand and real patient data. However, identifying patient details were not made available to the researchers – only an internal patient identifier was made available. This research was approved under the University of Auckland Human Participants Ethics Committee protocol number 2007/078.

#### 3.1 Interactive Development of a QAR

In order to develop the criteria for the QAR we conducted a series of sessions with the collaborating general practice. This general practice formulated an expert panel for this work consisting of five members, two GPs, the practice manager and two nursing staff. During the first meeting the opportunity was given to the expert panel to propose suitable criteria for auditing their management of patients with chronic illness, focussing mainly on the domain of hypertension and its common comorbidities.

Patient numbers for the required criteria were then calculated and these results were discussed at the next session. This iterative process confirmed and denied initial hypotheses – for example, it confirmed adherence issues and on the other hand, indicated a relatively low rate of contraindicated problem-drug interactions. After several such iterations between the expert panel and the researchers, a set of specific quality indicators (QIs) pertaining to management of hypertension were decided on which provides the basis for the QAR. The final set of criteria that were formulated were categorised under the following three main sections:

- **Descriptive:** These give a general description of the extracted electronic health records from the PMS.
- **Supportive:** These support the practice performance with an eye to quality assurance

(relatively high numbers are indicators of good performance); and

- **Cautionary:** These instruct about the alignment of the practice to clinical practice guidelines and best practice (cases registering in these categories are recommended for review).

#### 3.2 PMS Data Extractions

De-identified patient data was extracted from the PMS of the general practice and stored in a Microsoft (MS) Access 2003 database. However, the expert panel is still able to identify the patients for further follow-up on their cases if required by using the internal patient identifier (e.g., “M004162”) the researchers are given. The extracted dataset contains all required patient information for the research within a selected date range, on:

- Demographics (age in years, gender, ethnicity as coded in the PMS)
- Dates of encounters
- Classifications/ Problems
- Prescriptions
- Blood pressure measurements
- Laboratory measurements (screening test results held in the PMS, as agreed between the investigators and the expert panel).

The data extract spans from the time of extraction to 18 months prior with the exception of Classifications/Problems, which are relevant for an indefinite time with respect to chronic illness and hence were extracted for five years back.

#### 3.3 Data Cleaning and Preparation

The initial data extract was stored as raw tables in our MS Access database. The PMS we extracted the data from is a commercial package that is widely used by GPs in NZ and does not provide direct access to its internal database structure. It does provide a database querying interface that lets an interested user extract any required data and save this information into plain text files, but however a disadvantage is that if the database fields are of type *memo* (used mainly for lengthy fields such as notes, storing lab results and so on), the resultant files include a lot of control (i.e., formatting) characters. These control characters were filtered out during the data cleaning phase and MS Access Visual Basic for Applications (VBA) modules were used to achieve this.

Blood pressure measurements also needed some cleaning and processing. Within the PMS, there are two ways of entering BP values, one is to enter the values directly into the BP fields provided in the software, and the other is to enter the values into the physician notes field with a backslash followed by the letters *bp* or *BP* (i.e. \bp or \BP). However there were many instances where BP values were simply entered into the the notes field without following this

convention; “BP - rt arm sitting 190/90”, “rpt Bp 150/85 at 2.15 pm, felt better...” for example. All such instances of BP measurements were extracted from notes and added to the BP table in our database. Further, some BPs were correctly entered into the field provided within the PMS and were also entered into the notes field, in such cases the one entered into the notes field was ignored.

After the data was cleaned and prepared to be processed for our analysis, the prescription lasting durations were validated based on instructions (*signatura*) given by the GP consisting of dosing, frequency, repeats (refills) and a duration (computed by the PMS) per prescription. PMS-computed duration was accurate except where the GP had overridden default dosing instructions, wherein we computed a corrected duration; e.g. “take 10mg od” of Plendil ER was interpreted as a directed consumption of 4\*(2.5mg Tab Plendil ER)\*1 because Tab Plendil ER is available only in strength of 2.5mg (Gaikwad, Warren and Kenealy 2007).

### 3.4 Therapeutic State Transition Model

The requirements of the expert panel included quality indicators such as “patients who have been on concurrent therapy with ACEi/ARBs and diuretics” and “patients with lapse in anti-hypertensive medication”, where a *lapse* in anti-hypertensive therapy is said to commence when all anti-hypertensive medications, if taken as directed from the day of prescribing, run out (brief lapses are expected and may not be problematic where the patient has retained some prior supply). To satisfy requirements such as these, we used the therapeutic state transition model set forth by Warren et al (Warren et al. 2005) and then further enhanced by Gadzhanova et al as described in (Gadzhanova et al. 2007).

According to this model, each prescription produces two events – one marking the start of the prescription and another implicit event marking the expected end of the prescription if directions (dose, frequency and repeats/refills for example) given by the GP were properly adhered to. By using various state variables to denote antihypertensive (AHT) therapy in our domain

of interest (Table 1), we constructed a series of *therapeutic state transitions*, which are effectively points in time when the status of key aspects of a patient’s therapy change. This model is further enhanced by heuristically processing the states to avoid over-sensitivity with lapses (indicated by *Zero* state) of less than 90 days being coalesced into the prior state, as is any other state of less than 30 days duration.

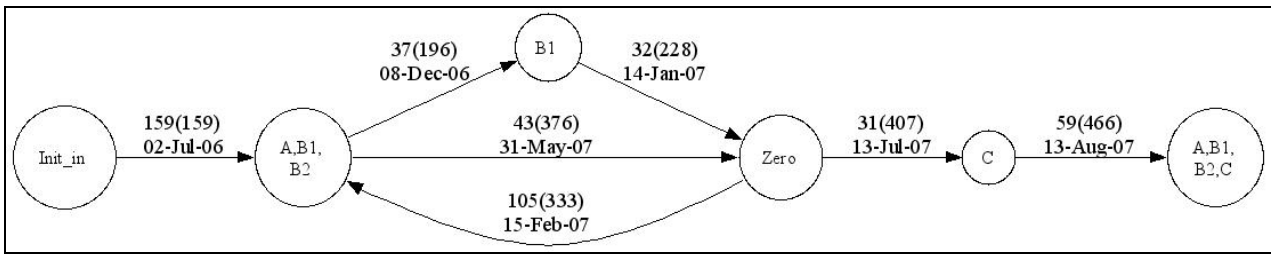
Based on these therapeutic states, we constructed a State Transition Overview Diagram (STOD) described elsewhere (Gaikwad, Warren and Kenealy 2007). This diagram simply presents a patient count of various state transition movements within the particular general practice during the evaluation period. This diagram was presented to the expert panel during the sessions described in Section 3.1 which further assisted the panel to refine the specific criteria.

As an example of how the therapeutic state transition model is applied to an individual patient, let us consider the Individual Path Diagram (IPD) (Gaikwad, Warren and Kenealy 2007) shown in Figure 1 for a hypothetical patient, and Figure 2 which shows a sample of the prescriptions this patient received during the data extraction period (18 months in this case) together with the corresponding state transitions. Figure 1 clearly shows how this patient has been in and out of AHT medication and such visual aids were used by the researchers to ensure that the resulting cases truly satisfied the criteria set forth by the expert panel. Figure 2 is quite self-explanatory with the comments/remarks column detailing out the important observations pertaining to the model, hence will not be explained further.

The beauty of the therapeutic state transition model is that it gives the analyser a suitable means of identifying patients on concurrent therapies as well as patients with lapses. It provides a higher level of abstraction compared to extracting the information from a raw prescriptions table. This is by no means to say that the state transition model does not have its own limitations and these are addressed later in the discussion section.

AHT state variables	ATC codes
A	ACE inhibitors, plain: C09A and Angiotensin II antagonists, plain C09CA
B1	Beta blocking agents, non-selective: C07AA and Beta blocking agents, selective: C07AB
B2	Low-Ceiling Diuretics, Thiazides: C03A, Low-Ceiling Diuretics, Excl. Thiazides: C03B, High-Ceiling Diuretics: C03C, Potassium-Sparing Agents: C03D, Diuretics And Potassium-Sparing Agents In Combination: C03E
B3	Calcium-channel blockers: Selective Calcium Channel Blockers With Direct Cardiac Effects: C08D
C	Calcium-channel blockers: Dihydropyridine derivatives: C08CA
D	alpha-adrenoreceptor antagonists: C02CA, Hydralazine: C02DB02, Clonidine: C02AC01

**Table 1: Therapeutic state variables and their respective Anatomical Therapeutic Chemical (ATC) codes**



**Figure 1: An Individual Path Diagram – The text on the arrow shows the transition date, the duration in each state and the total duration from the beginning of analysis period (within brackets). All durations are in days.**

<u>Prescription Date</u>	<u>TSV(s) for prescription(s) and duration(s)</u>	<u>State Transition (if any)</u>	<u>Comments/Remarks</u>
02-Jul-06	A (90) B1 (90) B2 (90)	Initial → A B1 B2	Transition from initial state to A B1 B2. A B1 and B2 drugs are scheduled to expire on 30-Sep-06.
09-Sep-06	A (90) B2 (90)		New prescriptions issued before previous ones fully expired. No change in states since patient still has A B1 and B2 drugs. A and B2 are scheduled to expire on 08-Dec-06.
16-Oct-06	B1 (90)		B1 would have expired on the 30-Sep-06, but since duration between this and 16-Oct-06 is less than 30 days no state transition occurs (heuristics). B1 is scheduled to expire on 14-Jan-07.
08-Dec-06		A B1 B2 → B1	A and B2 expire. Patient is only on B1. Class A medications are compellingly indicated for diabetes, so an alert will need to be raised if the patient was diabetic, unless current BP measurements are in the normal range.
14-Jan-07		B1 → Zero	B1 expires. Patient is on no medication and alert is required, especially if no controlled BP measurements (checking of BP is required since the patient could have been taken off medication and put on dietary management).
15-Feb-07	A (90) B1 (90) B2 (90)	Zero → A B1 B2	New prescriptions issued. A B1 and B2 are scheduled to expire on 16-May-07 and patient is on state A B1 B2.
02-Mar-07	A (90) B1 (90) B2 (90)		New prescriptions issued before previous fully expired. No change to states since patient is still on A B1 and B2. All prescriptions are scheduled to expire on 31-May-07.
31-May-07		A B1 B2 → Zero	A B1 and B2 expire. Again the patient is on no medication and alerting may be necessary.
13-Jul-07	C (90)	Zero → C	New prescription issued for C. Due to expire on 11-Oct-07.
13-Aug-07	A (90) B1 (90) B2 (90)	C → A B1 B2 C	New prescriptions issued for A B1 and B2. Since C still has not expired, patient moves from C to A B1 B2 C. A B1 B2 scheduled to expire on 11-Nov-07.

**Figure 2: Prescription durations, their therapeutic state variables (TSVs) and corresponding state transitions for a hypothetical patient**

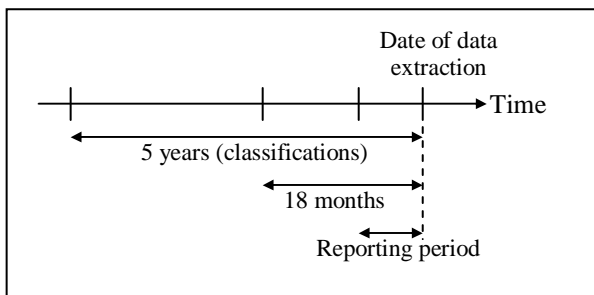
#### 4 Results

The main outcome of the present study is a methodology for generating a quality audit report based on a set of identified auditing criteria for process improvement in hypertension management. Here we

discuss some details of this report and the approach used.

It should be noted that although the data extracted span 18 months (with the exception of classifications which was for 5 years), the reporting window was narrower than this as shown in Figure 3.

The width of the reporting window (and classifications as well as period of data extraction for that matter) can easily be adjusted. For this iteration we chose a reporting period of 12 months as suggested by the expert panel. The reason for extracting prescriptions and other relevant data for 18 months (with the exception of classifications for which the reason was mentioned in Section 3.2) was to develop the gradual build-up of therapy using therapeutic state transitions. This was required merely due to the nature of chronic illness which usually span over an indefinite amount of time, hence will be inaccurate to say that a hypertensive patient was not on AHT therapy just because there was no AHT prescription at the very beginning of the reporting period (as therapy that started sometime before the beginning of the reporting period could have continued into the reporting period).



**Figure 3: The reporting window specific to the QAR in the current iteration**

#### 4.1 The Auditing Criteria

The auditing criteria we developed during the meetings with the expert panel have been put together in the form of a quality audit report containing three main sections – a descriptive section which contains general information about the practice, a section with supportive indicators which contains information the practice in general will want to drive to a 100 percent and a final section which contains cautionary indicators. Table 2 shows two examples from each

section of the QAR, one indicating a summative or an outcome related QI and the other relating to a process or a treatment.

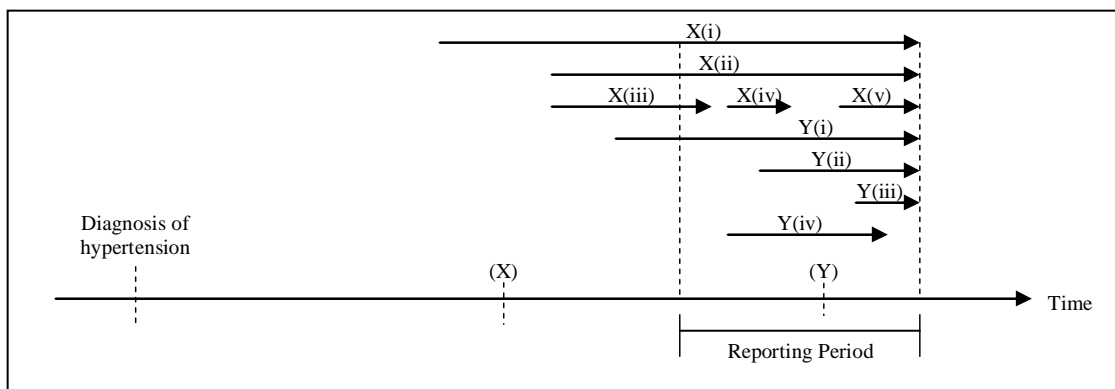
The supportive and the cautionary sections of the QAR contain quality indicators under several subcategories. BP related, prescription related, effective combination therapy, continuity of therapy and drug-problem indications constitute the supportive section while the subcategories – generic (for indicators such as “patients classified with hypertension and not prescribed with anti-hypertensive agent(s) within 90 days of classification”), BP related, lack of continuity of therapy, drug-drug interactions, drug-problem interactions and monitoring constitute the cautionary section.

Various temporal issues related to the quality indicators included in the QAR warrant a discussion here as well. For example, it is required that patients with diabetes mellitus (DM) be on ACEi/ARB throughout and therefore let us consider a seemingly simple indicator such as “patients classified with hypertension and diabetes mellitus, with an AHT prescription within the last 12 months after classification of hypertension, and not on ACEi/ARB any time during the reporting period”. To make the issue slightly more challenging let us also consider a reporting period of 3 months instead of 12 months (mainly for illustration purposes, since sometimes prescriptions are issued for shorter or longer periods than 3 months – which is the norm – and using a period of 12 months we will never have a single prescription covering the entire period).

There are several factors that need to be considered when determining the number of patients that satisfy this criterion. The first part of the criterion, “Patients classified with hypertension and diabetes mellitus, with an AHT prescription within the last 12 months after classification of hypertension” is relatively straight forward and requires a simple query where only two temporal constraints need to be met – i) the patient had an AHT prescription within the last 12 months; and ii)

Type of statistic	Summative/ Outcome	Treatment/ Process
<b>Descriptive</b>	Number (percentage) of active patients classified with hypertension as of 8 May 2007	Number (percentage) of patients classified with hypertension and prescribed ACEi or ARB during the reporting period
<b>Supportive</b>	Number (percentage) of patients classified with hypertension with systolic/diastolic BP less than or equal to 140/90mmHg (on last BP reading)	Number (percentage) of patients with active prescriptions for more than one antihypertensive agent as of 8 May 2007
<b>Cautionary</b>	Number (percentage) of patients with three or more consecutive BP measurements over 160/100mmHg (last measurement during the reporting period)	Number (percentage) of patients classified with hypertension and diabetes with lapses in ACEi or ARB during the reporting period

**Table 2: Examples of types of QAR statistics for patients classified with hypertension**



**Figure 4: Timeline illustrating temporal relationships amongst treatment, classification and reporting period.**

the prescription date was on or after the classification date of hypertension. The rest of the statement, “not on ACEi/ARB any time during the reporting period” is somewhat not as straightforward since there can be many possibilities depending on the date of classification of DM as shown in Figure 4. (X) and (Y) in this figure denote possible diagnosis dates for DM. The durations represented by the arrows with X(i-v) and Y(i-iv) are related to diagnosis dates (X) and (Y) respectively. For simplicity we assumed that the diagnosis of hypertension was earlier than (X) and (Y) and the reporting period.

If diagnosis of DM was at (X), then patients covered by ACEi/ARB prescriptions denoted by X(i) and X(ii) should not be selected since in both these cases there was continuous therapy during the reporting period. However cases X(iii), X(iv) and X(v) will satisfy our criteria since there was lapse in ACEi/ARB after classification of DM *during* the reporting period. On the other hand if DM diagnosis date was Y, then the only cases where no lapse in therapy occurred will be Y(i) and Y(ii). It is important to note that Y(ii) could have begun even on (Y) since this would mean the GP quite rightly prescribed ACEi/ARB as soon as (i.e. on the same day) diagnosing the patient with DM. Y(iii) and Y(iv) both have lapses *during* the reporting period, *after* being classified with DM, hence will satisfy our criterion. It needs to be noted that in this case we considered a reporting period of 3 months and that X(i), X(ii) and Y(i) were prescriptions issued for longer than 3 months while X(iv) and Y(iv) were issued for a shorter period. A definite statement about durations of X(iii), X(v), Y(ii) and Y(iii) cannot be made based on the diagram.

For some other challenging temporal issues related to auditing management of chronic illness, please refer to work by (Warren et al. 2007).

## 4.2 Implementing the Criteria

There were several options for quality audit report generation. Using the reporting functionality of MS Access was certainly appealing since access to the data within the same database management system (DBMS) would be easier than using an external package with the suitable drivers to access a MS Access database.

Building our own reporting engine using the reporting features of a high level programming language such as Visual Basic.net, C#.net or Java was another option. However after some discussion among the researchers, it was decided to use MS Word with the backend (for database connectivity, querying and other facilities) implemented in MS Word VBA. The main reason for this was the ease of creating the required layout using MS Word front-end; which was also the main drawback we encountered while trying to use the MS Access reporting functionality for our reporting purposes.

The quality indicators belonging to different sections (descriptive, supportive and cautionary) and subsections within them (such as *effective combination therapy*, *drug-problem interactions* and *drug-drug interactions* for example) were created in MS Word using standard tables. An MS Access query written in Structure Query Language (SQL) – the MS Access version of it rather, which is a subset of ANSI SQL 92 – was created to get the required statistic corresponding to each quality indicator and these were written while taking various temporal issues (some of which were discussed in Section 4.1) into account. For example, for the scenario depicted in Figure 4 the resultant SQL query is as per Figure 5 and is indicative of the nature of the complex SQL that is involved with most of the criteria requiring temporal constraints.

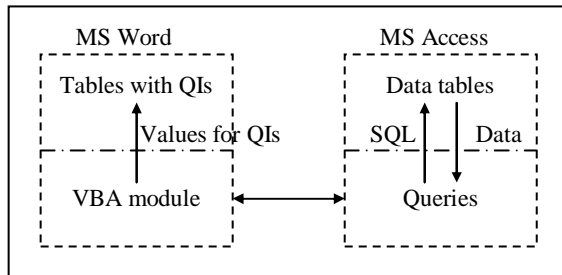
```
SELECT DISTINCT QAR_fPatientswAHTwHT.MMID
FROM QAR_EvaluationPeriod, (QAR_fPatientswAHTwHT INNER JOIN
QAR_Classifications_Diab ON QAR_fPatientswAHTwHT.MMID =
QAR_Classifications_Diab.MMID) INNER JOIN QAR_NextState ON
QAR_Classifications_Diab.MMID = QAR_NextState.MMID
WHERE
QAR_NextState.To_state Not Like "**A*" AND
QAR_NextState.Event_date >=
QAR_Classifications_Diab.CLASSDATE AND
((QAR_NextState.From_state Not Like "**A*" And
QAR_NextState.Event_date >=
QAR_EvaluationPeriod.analysis_begin AND
QAR_NextState.Event_date <=
QAR_EvaluationPeriod.analysis_end)
OR
(QAR_NextState.Event_date <=
QAR_EvaluationPeriod.analysis_begin AND
QAR_NextState.Event_date + QAR_NextState.duration >=
QAR_EvaluationPeriod.analysis_end)
```

**Figure 5: An example of a temporal query in SQL**

In this query we already have patients who have had an AHT prescription within the last 12 months after being classified with hypertension in table QAR\_

fPatientswAHTwHT. The QAR\_Classifications\_Diab table contains all patients classified with DM. The QAR\_NextState contains information about any state transitions that may have occurred, similar to Figure 2, while QAR\_EvaluationPeriod stores information about the reporting period.

All the required queries were created and stored in the MS Access database and were then called by the VBA code in MS Word. An overview of this process is shown in Figure 6.



**Figure 6: Overview of the QAR generation process**

### 4.3 Iterative Validation

The reporting criteria were finalised after five meetings with the expert panel. At each meeting, the QAR underwent progressive evaluation and revision, and although its initial focus was CVD risk management (i.e. hypertension related), the concerns of the expert panel have brought forward diabetes mellitus and renal failure as two other key issues. Therefore the result has gradually tended toward a QAR that focuses on AHT prescribing with consideration of key comorbidities.

Co-author JK is also one of the clinical staff at the general practice who has full access to the patient information. Initial validation of the QAR was performed by drawing a random sample of 10 patients, approximately five from each, supportive and cautionary sections and giving these patient identifiers to JK to review.

To formally evaluate the quality of our reporting, we intend to use individual de-identified cases drawn randomly based on the criteria in the QAR, 20 in each of the following categories:

- Patients in a cautionary category (e.g., with an apparent contraindicated use of beta-blocker due to asthma appearing on their problem list in the PMS).
- Patients under treatment to control any of hypertension, lipid or glycaemic status but that have NOT matched to any cautionary category in the QAR.

The expert panel will then review each of these 40 cases, blind to whether the case has been matched to one or more QAR criteria. The review protocol will involve review by the clinical staff of the PMS data and any hardcopy files that are maintained and completion of a review form shown elsewhere (Warren et al. 2007). The resulting classifications will allow

assessment (albeit with a somewhat broad confidence interval) of the sensitivity and specificity of the QAR cautionary categories as an indicator of high-quality chronic disease management within the scope of criteria considered.

## 5 Discussion

In this paper we have presented an initial methodology towards formulating a quality audit report based on a set of specific auditing criteria that can be used to improve the process of hypertension management. The set of quality indicators that were developed (using essentially a data mining approach) after a series of sessions with a general practice we are collaborating with have been put together in the form of a quality audit report and delivered under three main categories; descriptive, supportive and cautionary. We believe that the immediate direct use of this report will be for follow-up on the cohort of patients reported where potential actions for these patients may include review of the PMS record and possible patient recall or review of therapy at next visit. The report has undergone an initial, informal review and the results look very promising. A more formal evaluation of the QAR is underway where the staff at the general practice will review and comment on the patients reported by various QIs in the report.

Statistical reporting and retrospective auditing of general practice is not uncommon and previous studies do exist where similar work has been carried out as reported by Poluzzi et al in (Poluzzi et al. 2005), but a key difference between our work and most other work is the incorporation of various temporal issues, something that lies at the very heart of chronic disease management. Criteria such as “patients classified with hypertension and prescribed with ACEi/ARB” have been included by most audit reports but to the authors’ knowledge there have been no attempts in the past where criteria with multiple temporal constraints (such as “three or more consecutive BP measurements over 160/100mmHg with the last measurement during the last 3 months”) have been considered. We believe such criteria will greatly help general practice identify patients whose therapy for chronic illness need to be reviewed. Although not formally investigated yet, we also have some evidence indicating that our reporting will have high sensitivity and specificity.

We intend to revisit and review the current therapeutic state transition model to include other factors such as lab tests, blood pressure measurements and potentially diagnosis classifications as well. In the current model only therapy is considered; and inclusion of other factors will be beneficial to further increase sensitivity and specificity of our reporting that utilises this model.

While we are currently focusing on the process of clinical audit within a single practice, and with locally-defined and agreed reporting criteria, the concepts around aggregate analysis (for a group of practices, a region, or nationally) are not unrelated. CBG’s HealthStat (see <http://www.healthstat.co.nz>)

demonstrates the potential for similar reporting based on national-wide sampling of PMS data on short reporting cycles (e.g., weekly) and this could provide an attractive pool of clinical data for our auditing purposes.

As discussed previously, our criteria include a considerable amount of temporal issues which are currently implemented in standard SQL as shown in Figure 5. This SQL is complex in nature and hard to write and validate while taking the required temporal constraints into account. Therefore a goal of our architectural development is to make it easier to construct consistent and reliable queries of the type required. Chronus II developed at Stanford Medical Informatics (SMI) is an independent module capable of providing some level of abstraction for temporal queries (O'Connor, Tu and Musen 2002) while using a relational database. We are currently discussing with SMI the possibility of building on top of this module to provide a suitable layer of abstraction for our architecture.

Our current work indicates that the chronic disease auditing criteria of interest to clinicians fit several common patterns. While we have yet to formally define this taxonomy of criteria patterns, the patterns include such cases as: (a) failure to undertake, or persist, in treatment of a compelling indication; and (b) sustained failure to achieve a target level in an observation (such as BP). The existence of these pattern in turn indicates that it may be possible to formulate a query template graphical user interface to ease the process of criteria formulation. Therefore, building a software tool where clinicians can specify their own criteria in a user-friendly manner is also on our agenda. The main focus here is to provide a set of abstract concepts (such as classifications, concurrent therapy, last 3 encounters, last 2 BP measurements, comorbidities for example) together with relevant temporal constraints (such as after classification, during last 3 months and so on) where a user can easily specify the required criteria to be audited at the click of a few buttons (and possibly generate a QAR as well). This will help different practices customise the criteria in a way they feel is important after taking various local factors into consideration. Using the same (possibly the default) set of criteria will also provide the basis for different general practices to be compared for various management purposes, possibly include 'pay-for-performance' incentives.

In addition to further architectural development, our research aim is now to investigate interventions that may improve the clinical outcomes of patients where the QAR indicates such potential. This is particularly promising with respect to patients who simply need a reminder to return to the practice for continuity of their medication.

## 6 Acknowledgements

The authors acknowledge the support and participation of Health West Fono as essential to this research. We thank MedTech New Zealand for provision of research

licences of MedTech32 to The University of Auckland. This research was partially funded by a University of Auckland Doctoral Scholarship.

## 7 References

- (1997): The sixth report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. *Arch Intern Med*.
- Baker, R., Stevenson, K., Shaw, E. and Redsell, S. (2002): Principles for Best Practice in Clinical Audit: National Institute for Clinical Excellence. Radcliffe Medical Press.
- Chan, A. S., Coleman, R. W., Martins, S. B., Advani, A., Musen, M. A., Bosworth, H. B., Oddone, E. Z., Shlipak, M. G., Hoffman, B. B. and Goldstein, M. K. (2004): Evaluating provider adherence in a trial of a guideline-based decision support system for hypertension. *Medinfo*, **11**: 125-9.
- Didham, R., Martin, I., Wood, R. and Harrison, K. (2004): Information Technology systems in general practice medicine in New Zealand. *N Z Med J*, **117**: U977.
- Field, M. J. and Lohr, K. N. (1992): *Guidelines for clinical practice: from development to use.*, Washington, DC, Institute of Medicine, National Academy Press.
- Gadzhanova, S., Iankov, Ii, Warren, J. R., Stanek, J., Misan, G. M., Baig, Z. and Ponte, L. (2007): Developing high-specificity anti-hypertensive alerts by therapeutic state analysis of electronic prescribing records. *J Am Med Inform Assoc*, **14**: 100-9.
- Gaikwad, R., Warren, J. and Kenealy, T. (2007): The TAR Model: Use of Therapeutic State Transitions for Quality Assurance Reporting in Chronic Disease Management *12th International Health (Medical) Informatics Congress (Medinfo)*. Brisbane.
- Goldstein, M. K., Hoffman, B. B., Coleman, R. W., Musen, M. A., Tu, S. W., Advani, A., Shankar, R. and O'connor, M. (2000): Implementing clinical practice guidelines while taking account of changing evidence: ATHENA DSS, an easily modifiable decision-support system for managing hypertension in primary care. *Proc AMIA Symp*: 300-4.
- Grimshaw, J. M. and Russell, I. T. (1993): Effect of clinical guidelines on medical practice: a systematic review of rigorous evaluations. *Lancet*, **342**: 1317-22.
- Johnson, P. D., Tu, S., Booth, N., Sugden, B. and Purves, I. N. (2000): Using scenarios in chronic disease management guidelines for primary care. *Proc AMIA Symp*: 389-93.

- O'Connor, M. J., Tu, S. W. and Musen, M. A. (2002): The Chronus II temporal database mediator. *Proc AMIA Symp*: 567-71.
- Poluzzi, E., Strahinja, P., Vargiu, A., Chiabrande, G., Silvani, M. C., Motola, D., Sangiorgi Cellini, G., Vaccheri, A., De Ponti, F. and Montanaro, N. (2005): Initial treatment of hypertension and adherence to therapy in general practice in Italy. *Eur J Clin Pharmacol*, **61**: 603-9.
- Rea, H., Kenealy, T., Wellingham, J., Moffitt, A., Sinclair, G., Mcauley, S., Goodman, M. and Arcus, K. (2007): Chronic Care Management evolves towards Integrated Care in Counties Manukau, New Zealand. *N Z Med J*, **120**: U2489.
- Thiru, K., Hassey, A. and Sullivan, F. (2003): Systematic review of scope and quality of electronic patient record data in primary care. *Bmj*, **326**: 1070.
- Tunis, S. R., Hayward, R. S., Wilson, M. C., Rubin, H. R., Bass, E. B., Johnston, M. and Steinberg, E. P. (1994): Internists' attitudes about clinical practice guidelines. *Ann Intern Med*, **120**: 956-63.
- Warren, J., Gadzhanova, S., Stanek, J. and Iankov, I. (2005): Understanding caseload and practice through analysis of therapeutic state transitions. *AMIA Annu Symp Proc*: 784-8.
- Warren, J., Gaikwad, R., Mabotuwana, T., Kennelly, T. and Kenealy, T. (2007): Developing a Quality Audit Report for General Practice Prescribing for Hypertension: Methodology. *Health Informatics New Zealand (HINZ)* Rotorua, Health Care and Informatics Review Online.