Choosing and visualizing waiting time indicators in diagnostic medical imaging department for different purposes and audiences

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Abstract

**Background:** Providing information regarding waiting times in a diagnostic medical imaging department via an information system can facilitate quality and performance improvement.

**Objective:** The purpose of this study is to acquire new knowledge regarding the ways of choosing between different waiting time indicators according to the specific purposes and stakeholders of a diagnostic medical imaging department in a public hospital and propose an initial design for a system presenting visualization for such indicators.

**Methods:** The study employed methodological triangulation. First, clinical operational data from St. James’s Hospital’s radiology department was analysed in order to reach conclusions regarding the features of waiting time indicators. Subsequently, a qualitative study including in-depth interviews was performed. The selection of participants was strategic. Representatives of most categories of potential audiences of the system were interviewed. Thematic content analysis was performed on the interviews.

**Results:** The interviews confirmed the results of data analysis that the most informative and useful indicator is the X Percentile, while Median and Average waiting time indicators are also useful as complementary indicators. The study
showed that the purposes of the indicators are to obtain a dynamic view of the situation, detect the constraint points, provide an overview of performance, facilitate resource allocation, comparison between hospitals, better informed choice of alternative hospitals or exams and transparency.

**Conclusion:** The study suggests an interactive information system which will primarily present the X Percentile indicator using speedometers as a visualisation technique, but will also allow the user to seek for more detailed information.

**Keywords:** waiting lists, quality indicators, radiology, diagnostic imaging, quality improvement
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Glossary / List of abbreviations

EPR Electronic Patient Record
PACS Picture Archiving and Communication System
RIS Radiology Information System
NESWTDC National Elective Surgery Waiting Time Data Collection
MRI Magnetic Resonance Imaging
GP General Practitioner
NHS National Health Service
NTPF National Treatment Purchase Fund
KPI Key Performance Indicators
VBA Visual Basic for Applications
TCA Thematic Content Analysis
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1. Introduction

1.1. Background

Diagnostic medical imaging departments nowadays are expected to implement quality, safety and performance improvement programs (1). According to the second report from the Institute of Medicine *Crossing the Quality Chasm* (2) there are six aims for improvement in healthcare. More specifically, health care should be safe, effective, patient-centered, timely, efficient and equitable (STEEEP). In the case of diagnostic imaging departments the timeliness of health care, which according to the report can be achieved by “reducing waits and sometimes harmful delays for both those who receive and those who give care” (2), can be significantly improved by providing reliable and valid information regarding the waiting times (3). According to Kruskal B. et al in their study concerning quality improvement in radiology “the initial step is the gathering of relevant information, followed by the collection and analysis of quality and performance data”(1).

Nowadays a big amount of data deriving from different information systems, such as RIS (Radiology Information System), PACS (Picture Archiving and Communication System) and EPR (Electronic Patient Record), is being collected in each diagnostic medical department; however, in order to make it useful and meaningful, this data should be appropriately managed and presented to the right audience at the right time. In this case, it can prove to be a powerful tool that facilitates decision making. The Healthcare Financial Management Association (4) states in its educational report that data needs to be easily accessible and in a format that facilitates decision making. It is added that “essentially, it is about having the right metrics categorized and summarized in the right ways for the right audience” (5) In order to facilitate the processing of the data, visualisation is used, which is defined as “situations when quantified data which by itself is not visual…is transformed into a visual representation”(6).

More specifically, the operational data extracted from the clinical information systems can be processed in order to generate indicators relevant to waiting times. Various definitions have been proposed in order to determine clinical indicators, such as:

- Clinical indicators are tools used for measuring a process or outcome(7).
- A quantitative measure of an aspect of patient care that can be used as a guide to monitor and evaluate the quality and appropriateness of health care delivery(8).
Clinical indicators are used in order to measure certain aspects of health care delivery and inform the appropriate people in charge in order to facilitate decision making. There are various types of quality clinical indicators. Waiting time indicators are a type of process indicators(1). In order to promote the quality of healthcare, indicators are used to analyse the processes, see the changes that occur through time, propose improvements to the processes and apply those improvements. The use of clinical indicators can serve a variety of purposes, e.g. facilitate decision making, facilitate the comparison of performance of different hospitals, etc. According to Rubin Daniel, “radiology departments need to define for themselves a set of indicators and benchmarks that need to be established as part of a quality improvement program”(9).

In order to get a deeper understanding of how waiting lists are formed, it would be useful to present certain fundamental terms. According to the National Health Service (NHS) of United Kingdom one of the main reasons for the development and increase of waiting lists is the variation or mismatch in capacity and demand (10). NHS provides us with the following definitions:

- **Demand**: All the requests (in case of radiology scan orders) coming from all sources and how many resources they need.
- **Capacity**: Resources available to do work.
- **Activity**: All the work done. The activity is often less than available capacity.
- **Backlog**: Previous demand that has not been yet dealt with, appearing as a backlog of work (or waiting list). It appears when demand exceeds capacity.

Calculating the above mentioned measures can help improving the entire patient process by detecting where the problem lies and taking action in order to solve it. It facilitates the understanding of the reasons why the backlog or waiting lists form and therefore is a useful tool to avoid them. It is essential in order to avoid waiting lists growing excessively.

A search of literature about quality indicators related to waiting times and lists resulted in the list of indicators presented in Table 1. Those are the indicators that have already been proposed or used in information systems related to radiology and other medical fields.
Table 1 Waiting time and list indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average time</td>
<td>The average time from the reception of the order to completion of image acquisition (11)(12)</td>
</tr>
<tr>
<td>Median time (or 50th Percentile)</td>
<td>The time within which 50% of the scans were completed</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>The time within which 90% of the scans were completed</td>
</tr>
<tr>
<td>Percentage meeting benchmark</td>
<td>The percentage of scans that were completed within the established benchmark time (12)</td>
</tr>
<tr>
<td>Proportion of patients waiting more than N</td>
<td>Proportion of patients waiting for more than a certain specified amount of time (13)</td>
</tr>
<tr>
<td>Waiting list</td>
<td>Number of orders which have been received, however the scan has not been completed yet</td>
</tr>
<tr>
<td>Referral wait time for routine outpatient diagnostics</td>
<td>The length of time to the next available referral appointment slot for a scan</td>
</tr>
</tbody>
</table>

It should be noted that according to the definition given by the Canadian Institute for Health Information, benchmarks “express the amount of time that clinical evidence show is appropriate to wait for a procedure”(14). The benchmarks referring to diagnostic medical imaging have not been established in many countries, therefore this indicator cannot be used universally.

Potential audiences that could benefit from the information conveyed by waiting time indicators include the following categories:

- Clinicians: including hospital doctors, radiologists, GPs.
- Management positions: this category includes people making managerial decisions. They could work in hospitals, organizations relevant to healthcare or government.
- Patients

In order to achieve the desirable effect, the waiting time indicators should be calculated and presented to the above mentioned audiences at the right time. Use of informatics methods could play a significant role in this process. Several attempts have already been made in this area. One of the most prominent examples is the web site (14) created by the Canadian Institute for Health Information in the framework of the “10-year plan to strengthen health care” in Canada (15). This web site displays the waiting times in five priority clinical areas including diagnostic imaging (12).
Another initiative in the framework of the same attempt in Canada is the Ontario Wait Time Information Program which also included the development of a website that provides information regarding waiting times (16). Similar attempts, though in another department such as elective surgery, have been made in Australia with the National elective surgery waiting times data collection (NESWTDC) published online (17). Both the Canadian program and the Australian publication mention the 90th Percentile waiting time indicator, however without any justification of its usage. Another example of presentation of different indicators, including waiting time indicators, would be the automated web-based graphical dashboard developed by Paul G. Nagy et al (11) which is used to display waiting time indicators amongst other types of metrics.

In Ireland, where this study took place, the National Treatment Purchase Fund (NTPF) (18) along with the Department of Health (19) and Health Service Executive (20), which is responsible for providing health and personal social services for the Republic of Ireland, has established the National Waiting List Management Policy according to which information technology should play a role in planning, managing and improving the quality, reliability and safety of provided healthcare and support effective decision-making. Additionally, it suggests that the hospitals should develop data information Key Performance Indicators (KPI) and that “waiting time performance dashboard should be implemented and produced weekly by the dedicated executive lead for the waiting list management project groups and should include overall hospital KPI’s…” The NTPF also provides the public with information regarding national waiting list data, however radiology is not yet included.

HealthStat is a performance information and improvement system which consists of a databank of performance information concerning Irish public health care. It is developed by the Health Service Executive and provides monthly results of different hospitals that are published online (21). Those results are presented in the form of metrics (indicators) including indicators that concern waiting times. The only indicator relevant to waiting times in diagnostic medical imaging presented by the HealthStat is the “GP to Hospital Referral Wait Times for Routine Outpatient Diagnostics” (which include Ultrasound, X-Ray, CT and MRI) which represents the length of time to the next available appointment slot for diagnostic medical imaging procedure (22).
1.2. **Problem definition**

Due to the importance of providing waiting times information in timely and appropriate manner for decision support, there is a need for more profound and systematic research regarding waiting time indicators, their usability, their purposes and characteristics as well as the appropriate ways to visualize them in order to optimize their usability. Different indicators have been used so far, without a sufficient justification of their choice (such as the 90th percentile). There is a room for further investigation regarding the preferences of the different potential audiences concerning which information would be useful to them, for which purposes and how they would prefer it to be presented.

1.3. **Aims**

The overall aim of this study is to investigate how the data that derives from the clinical information systems in a diagnostic medical imaging department can be used in order to support effective time and resource management. This study aims to define the features and purposes of waiting time indicators in order to produce new knowledge regarding the ways of choosing between them according to different stakeholders of a diagnostic medical imaging department in a public hospital. Additionally, the study aims to establish the preferences of the above mentioned stakeholders regarding which information would be useful to them, for which purposes and how they would prefer it to be presented. The results will inform the design of an information system which will present visualization for waiting time indicators in a diagnostic medical imaging department, including suggestions for which waiting time indicators should be presented and which visualisation option should be used.

1.4. **Research questions**

**Main research question** How to choose and visualize waiting time indicators calculated from the data extracted from information systems (such as EPR, RIS and PACS) using informatics in order to achieve effective time and resource management in a diagnostic medical imaging department of a public hospital?

In order to answer the main research question, the following sub-questions will be addressed:  
**Sub-question 1**: What features of waiting time indicators can be defined based on the data extracted from RIS, PACS and EPR that are relevant for choosing between them?
Sub-question 2: What purposes could the waiting time indicators serve?
Sub-question 3: Which of the waiting time indicators is the most appropriate for which purpose?
Sub-question 4: How do the preceding questions inform the design of a waiting time indicator visualization interface? (Which indicators should be included and how should they be visualized?)
2. Methods

In this chapter the study design and the study flow are presented. The methods used for data acquisition and analysis are also described along with the ethical considerations.

2.1. Study design

In order to provide answers to the research questions an applied analytical study was performed. An applied study “aims at finding a solution for an immediate problem” (23). The research can also be characterized as inductive, since general inferences were induced based on specific examples from reality and inductive reasoning moves from specific to general (24). The strategy used in the research was triangulation. It can also be characterized as methodological triangulation, as it is using more than one research method and data collection technique (25). More specifically, the study followed a qualitative approach, including in-depth interviews, along with other complementary qualitative and quantitative techniques. Triangulation is preferred over pure qualitative or quantitative approach for completion purposes, as it helps to increase the understanding of the subject under study, and to provide more valid and reliable results.

In more detail, the research initiated based on the extensive literature review which was performed in order to determine which waiting time indicators have already been proposed and visualised. The next step was an analysis of the clinical data deriving from the information systems of a diagnostic medical imaging department of a public hospital. The data was used in order to mathematically calculate the indicators (established in the literature review and analysed later) and make some initial conclusions regarding their features and characteristics. This step was necessary in order to gain a deeper understanding of the nature of waiting time indicators and also it facilitated the interviews that followed. The study continued with the conduct of in-depth interviews of the participants and concluded with the analysis and synthesis of all the previous findings, resulting in an initial design proposal for a system which will visualize the waiting time indicators in a medical imaging department.

This approach was chosen for a number of reasons. The first part provides an insight of the nature of data that can be collected in a diagnostic medical imaging department and the ways it can be used. It gives an idea of what kind of data is needed in order to calculate the indicators, what are the characteristics of the different indicators and what kind of conclusions can be made from that.
Subsequently, a phenomenological approach was followed including in-depth interviews which provide a perspective on the needs of the different potential audiences. This approach was chosen because it helps to identify the individual perspective of the audiences on the subject. The in-depth interviews were chosen over other data collection methods because they provide much more detailed information regarding the subject under study. The interviewees can reveal much more concerning their preferences and opinions. It also gives the opportunity to clarify certain points during the conversation, in case there are uncertainties. The interviews can also vary according to the position of the interviewee. It is also a more flexible tool that provides the interviewer with the opportunity to lead the interview in more efficient way depending on the responses. However, there are certain biases. Most importantly, due to the nature of the in-depth interviews it is only possible to obtain a limited number of them. Therefore the results cannot be generalized, as they express only the opinions of certain individuals. The quality of the collected information can also depend on the interviewer’s skills. An attempt has been made to perform interviews in unbiased manner, which was achieved by not using leading questions and letting the participants freely express their opinions. An attempt was also made to collect accurate and sufficient information and to include interviewees that represent all the possible different audiences.

2.2. Study flow

The study initiated on 13th of January when the first meeting was held with the clinical director of the radiology department of St. James’s Hospital and the main supervisor of the research. The initial meeting was followed by a literature review and background research. The literature review along with the development of the project plan lasted until beginning of February. Subsequently, the clinical operational data was acquired from the radiology department of St. James’s Hospital. Several meetings followed with the staff of the hospital in order to facilitate the analysis of the data. The analysis of the data and the interpretation of the results lasted until end of March. During the same period an ethics application was prepared in order to obtain ethical approval for the conduct of the research. Also, the interviewees were identified and contacted and the interview guide was developed. The interviews were carried out during the first two weeks of April. The transcription and analysis of the results followed until the end of April. The report was finalized by the 17th of May.
2.3. Data acquisition

2.3.1. Clinical operational data

The study initiated with analysis of clinical operational data. This data was acquired from the diagnostic medical imaging department of St. James’s Hospital in Dublin, Ireland. A central database was recently developed in order to collect data that derives from all the information systems that are currently used by the department. More specifically the information systems are: RIS (Radiology Information System), PACS (Picture Archiving and Communication System) and EPR (Electronic Patient Record). The data used in this study was anonymised in order to protect the confidentiality of the patients involved and did not include any sensitive personal information. The data that was analysed during this study concerns the time period between 01/01/2010 and 31/12/2012. It refers to the MRI modality, which was chosen as a representative one. The analysis included only one modality due to time limitations; however the results can be extended and generalized to other modalities as well. In order to ensure the validity of data, the data from the common database was compared to the one from EPR, which is the original data, and the average accuracy was estimated at 98% with a standard deviation of 0.7, which is a satisfactory percentage of accuracy for the purposes of this study. More specifically, the data used in this study included the following fields:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDER_DATE_ID</td>
<td>The date when the exam was originally ordered</td>
</tr>
<tr>
<td>ORDER_ID</td>
<td>The unique identifier of the order</td>
</tr>
<tr>
<td>ACCESSION</td>
<td>Accession number, identifies the modality, the year and the position of the order</td>
</tr>
<tr>
<td>EPISODE_NO</td>
<td>The unique number of the episode which led to the exam order</td>
</tr>
<tr>
<td>MODALITY</td>
<td>The modality (MRI, CT, ultrasound)</td>
</tr>
<tr>
<td>EXAM</td>
<td>The type of the exam (e.g. brain general, spine full etc.)</td>
</tr>
<tr>
<td>PATIENT_STATUS</td>
<td>Patient status (public, private, semi-private)</td>
</tr>
<tr>
<td>ORDER_PHYSICIAN_FULL_FORMATTED</td>
<td>Full name of the physician who placed the order</td>
</tr>
<tr>
<td>ORDERING_SPECIALTY_CODE</td>
<td>The code of the specialty placing the order (e.g. neurology, geriatric etc.)</td>
</tr>
<tr>
<td>Field</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PRIORITY</td>
<td>Priority (routine or urgent)</td>
</tr>
<tr>
<td>LOCATION</td>
<td>Location where the order is made</td>
</tr>
<tr>
<td>ORIG_ORDER_DT_TM</td>
<td>The date and time of the original exam order</td>
</tr>
<tr>
<td>REQUEST_DT_TM</td>
<td>The requested date and time of the exam</td>
</tr>
<tr>
<td>VETTING_DT_TM</td>
<td>The date and time of vetting if it was carried out</td>
</tr>
<tr>
<td>ORIGINAL_SCHEDULED_DATE</td>
<td>The date and time for which the exam was ordered</td>
</tr>
<tr>
<td>CANCEL_DT_TM</td>
<td>The date and time of the cancellation of the exam (if cancelled)</td>
</tr>
<tr>
<td>START_DT_TM</td>
<td>The date and time when the exam was started</td>
</tr>
<tr>
<td>COMPLETE_DT_TM</td>
<td>The date and time when the scan was completed</td>
</tr>
<tr>
<td>CHECK_IN_DATE</td>
<td>The date and time of the check in of the patient</td>
</tr>
<tr>
<td>DICTATED_DATE</td>
<td>The date and time of dictation by the radiologist</td>
</tr>
<tr>
<td>FINAL_DATE</td>
<td>The date and time when the report was finalized</td>
</tr>
<tr>
<td>CANCELLED_BY</td>
<td>Name of the person who cancelled the exam (if cancelled)</td>
</tr>
<tr>
<td>CANCELLED_REASON</td>
<td>The reason for the cancellation (if cancelled)</td>
</tr>
<tr>
<td>CANCELLED_BY_POSITION</td>
<td>The position of the person who cancelled the exam (if cancelled)</td>
</tr>
<tr>
<td>ENCOUNTER_TYPE</td>
<td>The type of encounter (outpatient, inpatient, emergency)</td>
</tr>
</tbody>
</table>

### 2.3.2. In-depth interviews

Additional data was acquired through in-depth interviews. Five in-depth interviews were performed. The interviews were performed based on the developed interview guide, as in Appendix B. The guide was facilitating the conduct of the interview, however the structure of the interviews was not very strict, depending on the flow of the conversation with certain variations based on the position and role of the participant. In the beginning, the interview focused on the responsibilities and workflow of the participants, what kind of decisions they are making, what kind of information would facilitate those decisions and whether it is available for them now or not. Then the interview focused on the waiting time indicators, whether they would consider them useful or not, which purposes they would help serve, which indicator they would consider to be the most useful. In the final part the participants were asked to give their opinion regarding the different visualisation options (Appendix C) and features of a potential information system.

It should be noted that the participants can be characterized as informants rather than respondents, who according to the definition given by Lewis-Beck et al are “individuals who are
interviewed in a more in-depth, less structured manner (semi-structured, un-structured interviews), most often in a field setting” (26). The sampling technique was purposeful sampling. That means that the selection of the participants was strategic and not random. Maximum variation was the most important principle in order to ensure heterogeneity (27). An attempt was made to include representatives of all the categories of potential audiences of an information system which would present information regarding waiting times in a diagnostic medical department of a healthcare facility. Some of the participants in the interviews served double positions. The positions represented by the participants are the following:

- Consultant radiologist
- Consultant Physician
- General Practitioner (GP)
- Clinical Director
- Clinical Lead
- Director of Performance Improvement

The participants were interviewed in their own settings.

2.4. Data analysis

2.4.1. Clinical operational data

During the literature review a list of waiting time and list indicators was established. The next step was to analyse the data acquired from the diagnostic medical imaging department of the hospital. The analysis was made using Microsoft Excel and Visual Basic for Applications (VBA) software. First, the data was observed in order to obtain an understanding of the workflow and the steps of the process. The list of indicators was updated based on those findings. Subsequently, using the above mentioned software tools, some of the indicators from the updated list were calculated. In order to calculate the indicators, the first step was to identify the fields of the data that were necessary for the calculations. Those fields are presented in the following table (Table 3).
Table 3 List of data fields used for the analysis of data

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDER_DATE_ID</td>
<td>The unique ID of the date when the exam was originally ordered</td>
</tr>
<tr>
<td>EPISODE_NO</td>
<td>The unique number of the episode which led to the exam order</td>
</tr>
<tr>
<td>ORIG_ORDER_DT_TM</td>
<td>The date and time of the original exam order</td>
</tr>
<tr>
<td>COMPLETE_DT_TM</td>
<td>The date and time when the exam was completed</td>
</tr>
<tr>
<td>FINAL_DATE</td>
<td>The date and time when the report was finalized</td>
</tr>
<tr>
<td>ENCOUNTER_TYPE</td>
<td>The type of encounter (outpatient, inpatient, emergency)</td>
</tr>
</tbody>
</table>

Additionally, the data was checked for missing values. The Average time, Median time, X Percentile (all types) and Waiting list indicators (listed in Table 4) were mathematically calculated and visualized in different types of graphs (e.g. line or bar charts). The indicators were calculated weekly and monthly. The rest of the indicators mentioned in Table 4 could not be calculated either due to lack of established benchmark (Percentage meeting benchmark, Proportion of patients waiting more than N) or due to insufficient data (Time to next slot).

For example, in order to calculate the weekly average time between the time the exam was ordered and the time it was completed for different types of patients (inpatients, outpatients, emergency), the following steps were followed:

1) The difference between the date and time of the order and the completion of it (COMPLETE_DT_TM − ORIG_ORDER_DT_TM).
2) The week number was established for each order (e.g. the order which was made on 04/01/2011 relates to week number 2).
3) An algorithm was developed which calculates the average length of waiting time each week taking into account the different types of patients and producing results for each type (the algorithm can be found in Appendix B).

After the calculation of the indicators, the results and the created charts were analysed in order to reach logical conclusions regarding the features of different types of indicators and their characteristics. The results are covered in section 3.1.

2.4.2. In-depth interviews

The next step after the conduct of the in-depth interviews was transcription. After all the interviews were transcribed, Thematic Content Analysis (TCA) was applied. TCA is a descriptive
presentation of qualitative data, which has the form of interview transcripts (28). The following steps were followed during the analysis:

- All the parts of the transcripts that were not relevant to the topic of inquiry were identified and excluded.
- From the remaining parts of the transcripts, each distinct unit of meaning was marked. This means that each interview was broken into smaller units, according to their meaning.
- Units similar in their meaning were put together and labeled with particular keywords taken from the text. In this way several themes emerged.
- All the themes were read again and units were redistributed in case it was needed.
- In the end a certain number of final themes were determined. The result was a descriptive presentation of those themes based on the answers of the participants, including a number of direct quotes.

The results of the analysis are covered in section 3.2

2.5. Ethical considerations

The clinical operational data used in the current study was anonymised and therefore non-identifiable. A necessary subset of data was used and no individual could be identified from it, thus protecting the patients’ private and sensitive information.

In order to perform the interviews, a research ethical approval was obtained from the School of Computer Science and Statistics of Trinity College Dublin (the application form, the information sheet for participants, the informed consent form and the copy of the approval e-mail can be found in Appendix D). There was no relationship between the researcher and the interviewees; therefore the objectivity of the study was not compromised. There was also no conflict of interests. The nature of participation was voluntary. The participants were informed of the nature and goals of the research as well as of their right to withdraw, to make questions and to review any direct quotes. A written consent was requested in order to audio tape the interview and to reveal the identity of the participant in case it was necessary for the purposes of the research.
3. Results

This chapter presents the results of the analysis of data collected for this research. In the first section the results of the operational clinical data analysis are described. The results of the analysis of in-depth interviews are described in the second section.

3.1. Data analysis

3.1.1. List of indicators

By observing the clinical operational data from the diagnostic medical imaging department of St. James’s Hospital, it became obvious that the list of waiting time and waiting list indicators in Table 1, drawn from the literature, is somehow limited and that this list could be expanded.

Analysis of data as well as personal communication with the staff of the hospital indicated that the simplified version of the workflow of the department follows 3 basic steps. First the order for the scan is made by the hospital doctor (or a GP, who is not affiliated with the hospital). During the next step the ordered scan is performed and completed. However, in certain occasions for a number of reasons the order can be cancelled. In this case the procedure ends at this point. As a final step a radiologist finalizes the report related to the performed scan. This description derives from the available data and shows only the basic steps of the process. The process is depicted in the following Figure 1:

![Image of the simplified workflow of the diagnostic medical department of St. James's Hospital](image-url)

*Figure 1: The simplified workflow of the diagnostic medical department of St. James's Hospital*
The process described above indicates the existence of 3 different types of waiting times:

- Time from the moment the order is received until the scan is completed (O – C)
- Time from the moment the scan is completed until the report is finalized (C – F)
- Time from the moment the order is received until the report is finalized (O – F)

Additionally, it should be noted that 90\textsuperscript{th} percentile is not the only option that can appropriately indicate the waiting time of the patients. Possibly, in certain occasions (or modalities) another percentile would indicate the waiting time in a more helpful way for the audience (eg 75\textsuperscript{th} or 80\textsuperscript{th} percentile).

Moreover, the indicator “Referral wait time for routine outpatient diagnostics” can be generalized as well. Here, it will be defined as “Time to next slot”

Based on the above observations, Table 1 can be expanded to Table 4:

**Table 4: Waiting time and list indicators (expanded)**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average time O-C</td>
<td>The average time from the reception of the order to completion of scan (11)</td>
</tr>
<tr>
<td>Average time C-F</td>
<td>The average time from the completion of scan to the finalization of report</td>
</tr>
<tr>
<td>Average time O-F</td>
<td>The average time from the reception of the order to the finalization of report</td>
</tr>
<tr>
<td>Median time O-C</td>
<td>The time within which 50% of the scans were completed</td>
</tr>
<tr>
<td>Median time C-F</td>
<td>The time it takes for 50% of completed scans to lead to finalized reports</td>
</tr>
<tr>
<td>Median time O-C</td>
<td>The time it takes for 50% of the received orders to lead to finalized reports</td>
</tr>
<tr>
<td>X Percentile O-C</td>
<td>The time within which X% of the scans were completed</td>
</tr>
<tr>
<td>X Percentile C-F</td>
<td>The time it takes for X% of completed scans to lead to finalized reports</td>
</tr>
<tr>
<td>X Percentile O-F</td>
<td>The time it takes for x% of the received orders to lead to finalized reports</td>
</tr>
<tr>
<td>Percentage meeting benchmark</td>
<td>The percentage of scans that were completed within the established benchmark time (12)</td>
</tr>
<tr>
<td>Metric</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Proportion of patients waiting more than N</td>
<td>Proportion of patients waiting for more than a certain specified amount of time (13)</td>
</tr>
<tr>
<td>Waiting list</td>
<td>Number of people waiting at the moment (scans for which the order have been received, however the scan has not been completed yet)</td>
</tr>
<tr>
<td>Time to next slot</td>
<td>The length of time to the next available appointment slot for a scan</td>
</tr>
</tbody>
</table>

Finally, it should be mentioned that the indicators can be calculated separately for all different types of patients (outpatient, inpatient and emergency).

3.1.2. **Average or Median?**

![Average O-C vs Median O-C](image)

*Figure 2 Average O-C and Median O-C for all types of patients, year 2011, MRI*
The analysis of the data shows that in most cases there is a small number of people who are waiting for a long time, even though the majority is not, therefore the distribution is not normal. These few cases influence the average and as a result it does not represent the real picture. In this case median is a more informative indicator of the real situation. An example of the difference between average and median is represented on Figure 2. The data concerns all types of patients waiting for an MRI scan in 2011.

3.1.3. **Point-in-time or time period data?**

In order to answer the question whether the data used for the calculation of presented indicators should be for the current point-in-time or for a larger time period the fluctuations of the waiting times were observed. The conclusion of the observation was that in most cases, except for emergency patients, the waiting times change abruptly from day to day, therefore point-in-time data would not be very helpful.

*Figure 3 Average O-C for inpatients and outpatients, year 2011, MRI*
For example, as we can see on Figure 3, during the week 11\textsuperscript{th}-17\textsuperscript{th} of April 2011 the average waiting time for the outpatients was 68 days, however the following week 18\textsuperscript{th}-24\textsuperscript{th} of April 2011 the average waiting time was 31 days.

3.1.4. X Percentile

As mentioned previously, in chapter 3.1.2, the distribution of waiting times in diagnostic medical imaging in most cases is not normal and is positively skewed. This occurs due to few cases that wait for a very extensive period of time. The X Percentile indicator can exclude these cases. For example, on Figure 4 we can see that the majority of inpatients are waiting for not more than approximately 10 days and there are only few cases that wait longer than that. (The frequency on Figure 4 is presented on logarithmic scale in order to reduce the wide range of values and make the representation easier to interpret). From Figure 5, where we can see the distribution of cumulative percentage of the frequency, we can see that this number corresponds to approximately 90-95\% of the cases. The conclusion is that in this case, 90th Percentile or 95\textsuperscript{th} Percentile would be an appropriate indicator. However, this number might differ for different modalities, types of patients, etc. This analysis is based on a conversation with a staff member of radiology department of St. James’s Hospital (Seán Cournane 2013, oral conversation, April).
Figure 4 Distribution of frequency for waiting times (O-C) MRI, inpatients, year 2011 (Note: Frequency is presented in logarithmic scale)

Figure 5 Distribution of cumulative percentage of frequency for waiting times (O-C) MRI, inpatients, year 2011
3.2. In-depth interviews

The following section presents the results of the analysis of the in-depth interviews. During the analysis a number of themes were identified based on the answers of the participants. The list of the identified themes include the participants’ general and decision-making responsibilities, information which is useful for their decisions, information which is available to the participants at the moment, which purposes would the waiting time indicators help serve, evaluation of the proposed indicators, new indicators proposed by participants, visualisation options and the level of interaction of the information system.

3.2.1. Participants’ general and decision-making responsibilities

The participants gave a brief description of their responsibilities and the decisions they are making during their workflow. Some of the responsibilities can vary in different hospitals and organizations, however the main description is the same.

The responsibilities of a physician related to radiology mainly concern the ordering of tests (scans). The decision is often made in collaboration with a radiologist. The urgency of the procedure is also decided by physicians.

Consultant radiologists examine, interpret and report the results of a diagnostic test. In some cases radiologists perform some interventional procedures as well. They review the orders and decide upon their clinical appropriateness. Another one of their responsibilities is to provide consult service to physicians and discuss individual cases and management decisions.

The responsibilities of a GP relevant to radiology is to refer the patients for an exam (scan) to a hospital. They decide upon which type of exam should be performed and also which hospital to refer the patient to. At the moment in Ireland GPs can refer patients to any hospital of their choice, however they have different level of accessibility to procedures depending on the part of the country where they are located. For example, in some places GPs only have access to emergency departments and in others they can also refer patients for X-ray scans or even CT and MRI scans.

The duties of people who are responsible for the management inside the hospital (such as Clinical Directors) are to overview particular departments from a clinical point of view and from the point of view of efficiency. They have to ensure safety, efficiency and productivity. An
important part of this process is resource allocation. Management of the waiting times inside the particular department or the whole hospital also falls under their responsibilities.

The final category are people who are making decisions on national level (such as Primary Lead or Director of Performance Improvement). They are responsible for structural and operational changes in order to improve the care services in the country. With the goal of reducing the excessive waiting times they investigate the reasons of why they are formed. They compare national waiting times and intervene for example by producing guidelines or care pathways for clinicians in order to improve the situation.

3.2.2. Information useful for decisions

The information necessary for the physicians as well as GPs is how long the waiting time for each modality is. However, it should be mentioned that while a physician is referring for certain procedure, the input of the consultant radiologist is also very important for the final decision.

From the point of view of consultant radiologists, in order to make informed decisions they would need information regarding the waiting times in different modalities for different types of patients. Knowing which modalities have a very long waiting time would influence their decisions and the suggestions that they make to physicians during the meetings. Additionally, they would need to know how urgent is the referral, what are the clinical indications and the type of the patient (public or private).

According to a clinical director, the information needs of people managing the hospital would include the number of orders coming in (activity), the capacity, the absolute number of people on the waiting list and the approximate time it takes them to get examined. Additionally, it would be useful to have an idea of the maximum waiting time.

In order to make decisions on national level, information regarding the waiting times of each hospital is needed. This would include the waiting times during all the stages, since the order is made until the final report. Ideally, the same information should be available for each hospital in order to make the results comparable.

3.2.3. Information available now

The information available at the moment to the clinical and managerial staff of the hospital is mostly limited to the maximum amount of time that the patient will wait for a test. This can be
estimated by detecting the next available slot for a test. This kind of information can be extracted from the appointment schedule. According to the consultant physician personal communication plays an important role for gathering of information. Attempts have been made to deal with the cases of patients who wait for an excessive amount of time (for example by communicating with them and enquiring whether they still want to go through with the procedure) which are not considered successful. More specifically, clinical director №1 mentioned considering the way the excessive waiting times were managed until recently:

“I don’t think they ever tried to estimate the number of orders coming in on daily basis and they really just focused on people who were longest on the list. They would simply ring people if their waiting time was a year and ask them if they still want the test. As it turns out most of the people said they want the test, so it didn’t work very well.”

GPs are not provided with any information regarding waiting times at all. The only way of getting an approximate indication of the possible waiting time is upon communication with the hospital in order to schedule a procedure for a patient. However, this information can still be quite inaccurate. When asked about whether there is currently any information available the GP №1 mentioned:

“No, except the sort of information I gather when I ring up to get an appointment for a patient, then I get an idea. They say the patient should come in let’s say 2 weeks and you’re asked to send in the request form and the hospital sends out an appointment to the patient, but then you’re never sure how long that’s going to be. So it’s some sort of indication, but I think you need more than just an indication.”

The only information available to decision makers outside of the hospital environment derives from HealthStat system (mentioned in the introduction). This information is very limited and incomplete.

3.2.4. Which purposes would waiting time indicators help serve?

According to the participants the visualization of the waiting time indicators would be useful and it would help to serve the following purposes:

- **Obtain a more dynamic view of the situation**: The indicators help to obtain a dynamic view of the situation of each modality. People are still used to the paper based system which follows the pile system, without considering the general tendency of the waiting lists. Waiting time
indicators inform regarding which tendency each modality follows, whether it becomes more or less busy and where the spikes are, thus providing a more dynamic view of the general situation. As stated by clinical director №1, from the point of view of radiology department staff:

“People are used to requests coming in and then going in a pile. And then they would work from the bottom of the pile. And they would stay at the fixed work rate not paying any attention whether it’s going up or down and that’s the way people would think about it. They didn’t really try to look at things dynamically”

- **Detect the constraint points:** The visualization of indicators would make it easier to detect the constraint points which cause the delays. This happens when the demands exceeds the capacity resulting in a backlog. Since in certain modalities (such as MRI) the output is fixed (a certain fixed number of scans per day) it is not clear how long it takes for patients to get examined. Detecting the points where the problem starts makes it easier to understand the reasons for the problems and therefore to solve it.

- **Provide an overview of performance:** The waiting time indicators give an overall idea of the efficiency and performance of a specific department. This information is particularly important when changes are made. The indicators show whether the change has actually made any difference or not.

- **Facilitate resource allocation:** Indicators help to understand better the demands of each department and therefore facilitate the resource allocation, decide where to assign more staff or equipment.

- **Facilitate comparison between hospitals:** The use of the same waiting time indicators would facilitate the comparison between different hospitals. Subsequently, information regarding how each hospital is performing compared to national averages would probably motivate improvement.

- **Facilitate better informed choice of alternative hospitals or exams:** If there is an option between alternative exams, knowing which one has the shortest waiting time would facilitate the clinician to make a better decision. Additionally, if this information would be available to patients and GPs, they would have the opportunity to go or refer to the hospital with the least demand and help balance the system this way. Though, this does not work for more rural areas where there is no choice of different hospitals. However, even though the majority of the
participants found that waiting time indicators really help them with this choice, some of the clinicians mentioned that they already have a sufficiently good idea of the workload gained by personal communication.

- **Facilitate transparency:** Making the visualization of the indicators available to the public and the government facilitates transparency. As stated by consultant radiologist №1:

  "I think if we had much more transparent system where people could see what we are doing, they could see how things change, that would be easier for us; it would give people some sense of participation."

### 3.2.5. Evaluation of proposed indicators

The participants were asked which of the proposed indicators they consider to be the most useful and for which reason. The answers lead to the following conclusions:

- **X Percentile:** All of the participants considered X percentile to be the most useful indicator.
  
  First of all, according to them, it offers the most accurate estimation of how long each patient would have to wait for a test. The percentile offers the most objective view of the overall progress, in case changes were made. The average and the median, as opposed to the percentile, do not provide a good overall idea of the performance because some of the cases that are urgent can be processed very fast and some routine cases might take a very long time and it is especially the routine cases that delay the discharge of the patients, which can affect the overall efficiency of the hospital.

  As described by a clinical director, the most important advantage of the percentile is that it helps to separate the scheduled follow-up cases. There is a certain number of patients on waiting list, such as cancer or liver patients who have scheduled follow up appointments regularly. Those patients could be on a waiting list e.g. for a year, but they are not delayed because they are no available slots, but because their test is appropriately postponed. What happens now is that a lot of hospitals remove them from the waiting list, which is not appropriate because in this case, if their appointment is delayed, their waiting time is not reflected anywhere. Or else, their influence on the waiting times can be used as an excuse. The X percentile however would help to reflect the waiting times while excluding this category of
patients. The clinical director said the following regarding the patients who are waiting for a follow up appointment:

“So a big problem that other radiologists would have is that they want these people taken out, but of course how do you find them? How do you know who they are? Most order systems don’t have the level of sophistication to put in the requested date (as in scan desired date) and then the date they actually got it. So a lot of hospitals remove those people from the waiting list, but of course some of those people still wait. So they might say I want this test do be done in 3 months and it actually happens in 6 months. So the patient has waited 3 months but it happened 3 months after it was supposed to happen and yet they would take him off the list. So I’m not sure how to account for them except for to include them and use the 90\textsuperscript{th} or 80\textsuperscript{th} percentile or something to get rid of them that way.”

According to the same interviewee, the exact number which corresponds to the X in X percentile can be different for different modalities or types of patients. It depends on the number of follow ups that are usually scheduled. For example in a certain modality 10\% would be enough to exclude all the follow up appointments, therefore 90\textsuperscript{th} percentile would be an appropriate indicator and in another modality another number would be more accurate. However, it was proposed that it might be best to choose one number that would be a reasonable fit for all the modalities and types of patients in order to render the indications comparable.

- **Average and Median:** The average and the median waiting time are considered by the participants to be useful, as they give a certain general idea of the performance, however they don’t provide with a good estimation of how long a patient would have to wait for a scan, especially if there is no additional information regarding the patient (e.g. if it is a cancer patient or not).

- **Waiting list:** The absolute number of people on the waiting list was considered to be useful as it provides a general idea of the size of the problem. However, it is much more useful when combined with information regarding the capacity.

- **Time to next slot:** According to the interviewees, this indicator does not really reflect how the whole system is working, but it is considered useful by some of the participants and should be presented.
- **Other**: The rest of the indicators, such as Percentage meeting benchmark, Wait > N and Proportion of patients waiting more than N were not considered very informative or helpful. A reason for that might also be that no official benchmarks have been set in Ireland regarding radiological procedures.

### 3.2.6. Indicators proposed by participants

An additional indicator which was proposed by some participants was the fraction of the waiting list (absolute number of people waiting) divided by the daily activity (number of scans that can be performed per day). This number would be a good indicator of how long a patient would potentially wait for a scan. For example, if there are 500 orders waiting and the activity is 40 scans per day, then the waiting time of a patient would be estimated at approximately 12.5 days. While presented alone, it does not give a good indication of the reasons of the delay, however it does represent the current situation well. As described by clinical director №1:

>“It is like with the engine temperature of a car. If it is normal, then it’s ok, don’t worry. But if it’s high, it could be a number of reasons, but at least you know that it’s high.”

### 3.2.7. Visualisation options

The participants were presented with alternative options of visualisation of the indicators. The different visualisation options can be found in Appendix C. The type of graph that was chosen as the most comprehensive one is presented in Figure 6. (Figure 6 is an example of visualisation of an indicator and it presents the Average O-C indicator for all patient types, year 2011).

However, graphs were not considered to be the optimal way of visualizing indicators. The best choice for representing the information provided by waiting time indicators is by use of the speedometer or the traffic light metaphor, where the status is indicated by red, yellow and green colours, demonstrating the deviations from certain predetermined benchmarks. For example, such system was presented in Rubin’s study (9), where the speedometer metaphor is used to visualize clinical performance indicators (Figure 7).
This approach was considered as the most appropriate one as it is easy to comprehend, informative and it has already been used for visualization of performance, so the potential users are familiar with it. It instantly provides information about the constraint points of the system. Graphs are more useful for well-informed audience that will need much more detailed additional information in order to make decisions. The speedometer or traffic light metaphor method can only
indicate the status, whether it is good or not, without providing any explanation. However, for certain audiences that is all the information they need.

Finally, the participants were asked to choose between the visualisation of indicators that were calculated either on a weekly or a monthly basis. All of the participants commented that the monthly representation is much more clear, useful and less noisy. Therefore it is the preferable option.

### 3.2.8. Level of interaction

The majority of the participants agreed that an interactive information system would be the most appropriate choice. The best solution would be a system that provides the users with a very general overview, which however will offer them additional information regarding specific department, modality, type of patients etc. if needed. The information however should be provided in consistent manner, for example using the same type of visualisation and the same indicator for each separate unit. At the same time the system should remain simple to use and not require extensive training. However, an opinion that the system should not be interactive and should just consist of one screen present the maximum of necessary information was also expressed by a consultant physician.

### 3.2.9. Additional comments

Additionally, certain propositions regarding the features of a potential information system were made. For example, it was proposed that such an information system should include a direct booking option or should be integrated with another system which offers this feature. Finally, it was proposed that the system includes decision support features. More specifically, the system could assist the user with the decision whether the ordered scan is clinically appropriate or not.
4. Discussion

In this chapter the results presented in the previous chapter are discussed and the major findings of the study are presented. First, the answers to the research questions are provided followed by the analysis of the strengths and weaknesses of the study. Reflections regarding the meaning and generalizability of the study as well as regarding the relation of the research to other studies are described. Finally, recommendations for future research are made.

4.1.1. Sub-question 1

The first sub-question was what features of waiting time indicators can be defined based on the data extracted from RIS, PACS and EPR that are relevant for choosing between them. First, the list of indicators was expanded in order to fit the workflow of the diagnostic medical department and include each step of the process. Different types of waiting times were established, which is important, because this way the information needs of all different types of audiences will be covered. For example the waiting time between the original order and completion of the scan is useful for the physicians, while the waiting time between the completion of the scan and the final report is crucial for the radiologists. The list of indicators was also generalized, in order to be applicable to all diagnostic medical departments. For example, different benchmarks could exist in different countries.

It was also established that the average indicator appears to be increased in comparison with the median in case the distribution of the waiting times is not normal. The analysis of the data shows that in most cases there is a small number of people who are waiting for a long time. Those are in most cases scheduled follow-up appointments. These few cases influence the average and as a result it does not represent the real picture. In this case median is a more informative indicator of the real situation. Therefore, it should be preferred in most of the cases.

Additionally, the observation of the fluctuations of the data lead to the conclusion that in most cases the indicators should visualize larger time periods (more than a week) in order to be informative. For most patient types and modalities, except for emergency patients, the waiting times change abruptly from day to day, therefore point-in-time data would not be very helpful. It was not possible to make accurate estimations of the waiting times based on the data available.
from the previous week. Therefore, it is necessary to present the information for a larger span of time in order to make well-informed decisions.

Finally, as mentioned previously the distribution of waiting times in diagnostic medical imaging in most cases is not normal and is positively skewed. One of the reasons is that there is a certain number of people who are waiting for a long time for a scheduled follow up appointment. However, those patients are not waiting because of lack of available slots, but because their scan is appropriately scheduled for a certain date in the future. Therefore, they should not be included in the estimation of the waiting times, because then the indicators do not represent the real situation. The X Percentile indicator can solve this problem by excluding those cases.

4.1.2. Sub-questions 2 and 3

The second and third sub-questions concern the purposes of the waiting time indicators and which of the waiting time indicators established in the literature research is the most appropriate for which purpose. During the study it was established that the waiting time indicators can serve the following purposes:

- **Obtain a more dynamic view of the situation:** Waiting time indicators could help to visualize the general tendency of the waiting lists, whether they become bigger or smaller. They help provide a fast and accurate view of the situation in each department or modality. The progress can be easily followed and evaluated and measures can be taken in order to solve existing or potential problems. The indicators that are most appropriate for this purpose are the **Average time** (all types: O-C, C-F and O-F), **Median time** (all types), **X Percentile** (all types), **Percentage meeting benchmark** and **Waiting list**, as they provide a good representation of the general situation.

- **Detect the constraint points:** In order to solve a delay that is higher than appropriate it is important to detect the constraint point which causes it. Detecting this point will make it easier to understand the reason of the delay and therefore resolve the problem. The indicators that would be most appropriate for his purpose are the **Average time** (all types), **Median time** (all types), **X Percentile** (all types). For example, if there is a big delay in the waiting times for an MRI scan, by observing the Median time O-C and Median time C-F it to see where the delay lies, in the time between order and completion of the scan or in the time between completion of the scan and finalization of report. Having knowledge when in the workflow the delay is
occurring makes it easier to take the appropriate measures to solve the problem and reduce the overall waiting time.

- **Provide an overview of performance:** The indicators give a general idea of the performance and efficiency of each department or modality. In this way the performance can be observed over time. This information is especially useful in order to evaluate the results of any implemented changes. It also facilitates comparison. **All** of the above mentioned indicators (presented in Table 4) are useful for this purpose.

- **Facilitate resource allocation:** The indication of the performance additionally facilitates the decisions that concern resource allocation. The managerial staff of the hospitals needs to make decisions regarding the allocation of the resources, such as medical staff, equipment etc. Knowledge of constraint points and performance can facilitate those decisions significantly. The indicators that would be more appropriate for this purpose are the **Average time** (all types), **Median time** (all types) and **X Percentile** (all types).

- **Facilitate comparison between hospitals:** Establishing specific indicators which will be used by all the hospitals would facilitate the comparison between them. This would help the organizations that are overseeing the general state of health care in the country to make better informed decisions and would probably also motivate the hospitals that are not meeting the benchmarks to improve. **All** indicators (Table 4) would be helpful in order to serve this purpose.

- **Facilitate better informed choice of alternative hospitals or exams:** Knowledge of the waiting times of each hospital, department or modality would help the clinicians make better informed choices between alternative possible scans. This would help minimizing the waiting time for the patient. The indicators that are the most appropriate for this purpose are the **Average time** (all types), **Median time** (all types) and **X Percentile** (all types). Particularly the X Percentile gives the most realistic estimation of the time the patient will probably have to wait.

- **Facilitate transparency:** Transparency is important in order to make the processes visible to everybody and give the patients sense of participation. This purpose would be facilitated better by the **Average time** (all types), **Median time** (all types) and **X Percentile** (all types) indicators.
4.1.3. Sub-question 4

The fourth and final sub-question was: how do the preceding questions inform the design of a waiting time indicator visualization interface, including which indicators should be presented and how should they be visualized.

The results of the study suggest that the best solution would be an interactive system, which would initially present overall information and would subsequently allow the user to observe more detailed information regarding any choice of his/her interest (e.g. particular modality, type of patient etc.). The X Percentile indicator should be included in the system, as it was chosen by the participants the most useful one that helps to serve all the purposes established in sub-question 2. Other indicators (such as Average time, Median time, Waiting list) can also be presented. Another suggestion would be to present the fraction of waiting list divided by daily activity. The visualisation technique for the general overview will be the speedometer or the traffic light metaphor which will use colors (red, yellow, green) in order to indicate the status of the performance. However, the user will have the choice to view additional graphs by clicking on it in case he/she needs more detailed information regarding a specific unit. Finally, the information should be presented in a consistent way (same visualisation technique for each unit such as modality, patient type etc.).

4.2. Strengths and weaknesses of the study

The strengths of this study are:

- During the study there was access to real clinical operational data extracted from a diagnostic medical imaging department of a hospital. The accuracy of the data was examined and it was sufficient for the purposes of the study.

- The participants for the interviews were members of the clinical and managerial staff of the hospital and other organizations, as well as an external GP. Therefore, all types of audiences of a potential information system, besides the patients, were represented. The interviewees all had key positions, great amount of experience in radiology and were well qualified to offer their opinions on the subject.

- No major obstacles or unexpected events that would influence the results of the research occurred during the implementation of the study.
• The methodological triangulation that was applied ensured better validity. The analysis of the clinical data was complemented by interviews in order to reach valid conclusions regarding the subject.

• The findings of the study refer to a diagnostic medical department of a specific hospital. However, the results can be applied to other settings as well (other hospitals and departments). The conclusions regarding the waiting time indicators can also be relevant to other aspects of healthcare besides radiology. (More details regarding the generalizability of the study can be found in section 4.4).

• At the end of the study the research questions could be answered to a sufficient extent. The weaknesses of the study are:

• The perspective of the patients, which constitute one type of the audience of the potential information system, was not investigated. Due to time limitations it was not possible to include patients in the study. However, this investigation could be a potential subject of future research.

• Due to time and resource limitations it was not possible to interview more participants in order to reach more accurate and valid conclusions. Additionally, it was not possible to investigate more the different visualization options. Again, that could constitute the subject of a future research.

• Due to the previous limitations, the results of the study are not easily generalizable because they express the opinion of a limited number of people and can be influenced by their personal biases and preferences. That constitutes a common limitation of qualitative studies.

4.3. Results in relation to other studies

A number of studies have been performed regarding quality improvement in radiology (1,2,29–31). Some of them focused on the role of informatics in achievement of quality improvement, such as clinical dashboards (9,11,32,33). The role of quality indicators has also been researched (13,34–36). However, the features of waiting times indicators have not been investigated in particular. Several waiting time indicators have been identified and used in clinical information systems (dashboards), but the reason for their choice have not been explicitly justified. The purpose of this study was to fill this gap and complement the previous studies that refer to the use of indicators in information systems for quality improvement. The conclusions of this research can be used in
order to proceed with the development of an information system in a diagnostic medical department.

4.4. Meaning and generalizability of the study

The results of the study are significant as they provide new knowledge regarding the users’ perspective and needs of a potential information system that would present the waiting times of a diagnostic medical department. They provide us with an insight of what would be the most efficient way to convey the information regarding waiting times to potential users of such system. The conclusions of the study can be used for the development of a system, such as a dashboard. Specifically, in section 4.1.3 specific suggestions are provided regarding the features of the system based on the findings of the study.

Since most hospitals nowadays use similar information systems in radiology departments (such as RIS and PACS), they possess similar sets of data. If, based on that data, the same indicators are calculated, the results become comparable at a national level. The publication of those results would facilitate the management on a higher level and also have a positive effect on individual hospital performance by motivating them to reach the national standards.

Even though the results of a qualitative study including in-depth interviews cannot be easily generalized due to limited number of participants, general conclusions can still be made. In this case, the study was conducted in a particular hospital. However, this hospital has a similar structure, organization and available data with many other hospital, therefore the results can be generalized to other settings as well. Additionally, the results of the study could be useful to draw conclusions regarding waiting lists in other departments of a hospital as well, besides diagnostic medical imaging.

4.5. Future research

Due to time and resource limitations, there are several aspects of the subject that has not been investigated to a sufficient extent. First, a similar study could include more representatives of each type of audience, in order to confirm and extend the results of the current study. An additional study should also be performed which will investigate the perspective of the patients as a potential audience of an information system considering waiting times. Also, further research could investigate more additional options for the visualisation of the indicators. Additionally, a study
could be performed with the aim to define new waiting time indicators that have not been performed yet.

The next step would be the implementation and evaluation of a trial system, in order to investigate the effects. For example, a prototype system could be developed and tested by users. Observation could be used as an evaluation technique.
5. Conclusions

Efforts are being made in many diagnostic medical imaging departments to achieve improvement in quality, safety and performance. In order to achieve it, it is essential to make correct use of the large amount of data collected by different radiology information systems. The purpose of this study was to discover new knowledge regarding the way of using this data in order to provide a data visualization interface for effective time and resource management. Several information systems (e.g. dashboards) have already been developed and used in radiology departments in order to provide information that would facilitate decision making, however there is a lack of research concerning waiting time indicators. This research attempted to cover this lack and provide an insight into the ways of choosing and presenting them by use of informatics.

In order to provide an answer to the research question, several steps were taken. First of all, the data extracted from the information systems used in radiology departments of St. James’s Hospital in Dublin, Ireland was analysed in order to reach conclusions regarding the features of waiting times indicators found in the literature. Next, in-depth interviews were carried out with representatives of potential audiences of the system in order to investigate their opinions and find out more about the purposes of the indicators, their evaluation and the best way to visualize them. The interviews confirmed the results of data analysis that stated that the most informative and useful indicator is the X Percentile, while Median and Average waiting time indicators are also useful as complementary indicators. The study also showed that the purposes of the presentation of waiting time indicators are to obtain a more dynamic view of the situation, detect the constraint points, provide an overview of performance, facilitate resource allocation, comparison between hospitals, better informed choice of alternative hospitals or exams and transparency. Those purposes can be served by several indicators, however X Percentile is seen to be the best one to help achieve all of the goals. The findings were summarized in a suggestion for an interactive information system which will present the indicators using speedometers or traffic light metaphor, but will also allow the user to seek for more detailed information.

Certain aspects of the study can be investigated further in future research. For example, patients’ perspective and more different visualisation options could be possible subjects for future studies. Moreover, a prototype of an information system which will visualize waiting time indicators could be developed and evaluated by the users.
The results of the study are significant as they provide new knowledge regarding the users’ perspective and requirements of a potential information system used in radiology. They can be used as a guide during the development of such system and are useful in order to draw conclusions regarding waiting time indicators in general.
References


18. NTPF. National Treatment Purchase Fund (NTPF) [Internet]. 2013 [cited 2013 Apr 12]. Available from: http://www.ntpf.ie/


Appendix A

Weekly Average O-C algorithm

The following VBA algorithm estimates the weekly average waiting time between the placement of the order and its completion for each different type of patient (inpatient, outpatient, emergency). The algorithm is applied to an Excel sheet that contains the following fields:

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>ORIG_ORDER_DT_TM</td>
</tr>
<tr>
<td>D</td>
<td>COMPLETE_DT_TM</td>
</tr>
<tr>
<td>F</td>
<td>Column D – Column F</td>
</tr>
<tr>
<td>H</td>
<td>Week number (=WEEKNUM())</td>
</tr>
<tr>
<td>J</td>
<td>ENOUNTER_TYPE</td>
</tr>
</tbody>
</table>

The algorithm produces the weekly average times for inpatients (column K), emergency patient (column L) and outpatients (column M).

```vba
Sub week_Average()
    Dim myWeek As Range
    Dim mycell As Range
    Dim encTypesPerWeek As Range
    Dim inpatient As Range, emergency As Range, outpatient As Range
    
    'Get the maximum week number - optional'
    topWeek = Application.WorksheetFunction.Max(Columns("H"))
    'for weeks 1 to max'
    For weeknumber = 1 To topWeek
        Set inpatient = Nothing
        Set emergency = Nothing
        Set outpatient = Nothing
        
        'find all cells that have weeknum equal to weeknumber'
        'and get the same cells, two columns to the right (encounter type)'
        Set encTypesPerWeek = FindAll(Columns("H"),Cells, weeknumber).Offset(0, 2)
        
        'filter types of encounters'
        For Each mycell In encTypesPerWeek
            If IsNumeric(mycell.Offset(0, -4).Value) Then
                If mycell.Value Like "*Inpatient*" Then
                    'Inpatient cell'
                    Set inpatient = Union2(inpatient, mycell)
            End If
        Next mycell
    Next weeknumber
End Sub
```
ElseIf mycell.Value Like "*Emergency*" Then
    'Emergency cell'
    Set emergency = Union2(emergency, mycell)
ElseIf True Then
    'Outpatient cell'
    Set outpatient = Union2(outpatient, mycell)
End If
End If
Next

If Not inpatient Is Nothing Then
    'calculate average of inpatients and place result in column K'
    Set inpatient = inpatient.Cells.Offset(0, -4)
    Cells(weeknumber + 1, "K").Value =
    Application.WorksheetFunction.Average(inpatient)
End If

If Not emergency Is Nothing Then
    'calculate average of emergencies and place result in column L'
    Set emergency = emergency.Cells.Offset(0, -4)
    Cells(weeknumber + 1, "L").Value =
    Application.WorksheetFunction.Average(emergency)
End If

If Not outpatient Is Nothing Then
    'calculate average of outpatients and place result in column M'
    Set outpatient = outpatient.Cells.Offset(0, -4)
    Cells(weeknumber + 1, "M").Value =
    Application.WorksheetFunction.Average(outpatient)
End If
Next weeknumber
End Sub

Function FindAll(SearchRange As Range, _
    FindWhat As Variant, _
    Optional LookIn As XlFindLookIn = xlValues, _
    Optional LookAt As XlLookAt = xlWhole, _
    Optional SearchOrder As XlSearchOrder = xlByRows, _
    Optional MatchCase As Boolean = False, _
    Optional BeginWith As String = vbNullString, _
    Optional EndsWith As String = vbNullString, _
    Optional BeginEndCompare As VbCompareMethod = vbTextCompare) As Range
'FindAll
'This searches the range specified by SearchRange and returns a Range object
'that contains all the cells in which FindWhat was found. The search parameters to
'this function have the same meaning and effect as they do with the
'Range.Find method. If the value was not found, the function return Nothing. If
'BeginsWith is not an empty string, only those cells that begin with BeginWith
'are included in the result. If EndsWith is not an empty string, only those cells
'that end with EndsWith are included in the result. Note that if a cell contains
'a single word that matches either BeginsWith or EndsWith, it is included in the
'result. If BeginsWith or EndsWith is not an empty string, the LookAt parameter
'is automatically changed to xlPart. The tests for BeginsWith and EndsWith may be
'case-sensitive by setting BeginEndCompare to vbBinaryCompare. For case-insensitive
'comparisons, set BeginEndCompare to vbTextCompare. If this parameter is omitted,
'it defaults to vbTextCompare. The comparisons for BeginsWith and EndsWith are
'in an OR relationship. That is, if both BeginsWith and EndsWith are provided,
'a match if found if the text begins with BeginsWith OR the text ends with EndsWith.

Dim FoundCell As Range
Dim FirstFound As Range
Dim LastCell As Range
Dim ResultRange As Range
Dim XLookAt As XlLookAt
Dim Include As Boolean
Dim CompMode As VbCompareMethod
Dim Area As Range
Dim MaxRow As Long
Dim MaxCol As Long
Dim BeginB As Boolean
Dim EndB As Boolean

CompMode = BeginEndCompare
If BeginsWith <> vbNullString Or EndsWith <> vbNullString Then
    XLookAt = xlPart
Else
    XLookAt = LookAt
End If

'this loop in Areas is to find the last cell
'of all the areas. That is, the cell whose row
'and column are greater than or equal to any cell
'in any Area.

For Each Area In SearchRange.Areas
    With Area

If .Cells(.Cells.Count).Row > MaxRow Then
End If
If .Cells(.Cells.Count).Column > MaxCol Then
    MaxCol = .Cells(.Cells.Count).Column
End If
End With
Next Area
Set LastCell = SearchRange.Worksheet.Cells(MaxRow, MaxCol)

On Error GoTo 0
Set FoundCell = SearchRange.Find(what:=FindWhat, _
    after:=LastCell, _
    LookIn:=LookIn, _
    LookAt:=XLookAt, _
    SearchOrder:=SearchOrder, _
    MatchCase:=MatchCase)

If Not FoundCell Is Nothing Then
    Set FirstFound = FoundCell
    Do Until False ' Loop forever. We'll "Exit Do" when necessary.
        Include = False
        If BeginsWith = vbNullString And EndsWith = vbNullString Then
            Include = True
        Else
            If BeginsWith <> vbNullString Then
                If StrComp(Left(FoundCell.Text, Len(BeginsWith)), BeginsWith, BeginEndCompare) = 0 Then
                    Include = True
                End If
            End If
            If EndsWith <> vbNullString Then
                If StrComp(Right(FoundCell.Text, Len(EndsWith)), EndsWith, BeginEndCompare) = 0 Then
                    Include = True
                End If
            End If
        End If
        If Include = True Then
            If ResultRange Is Nothing Then
                Set ResultRange = FoundCell
            Else
                Set ResultRange = Application.Union(ResultRange, FoundCell)
            End If
        End If
    End If
    Set FoundCell = SearchRange.FindNext(after:=FoundCell)
If (FoundCell Is Nothing) Then
  Exit Do
End If
If (FoundCell.Address = FirstFound.Address) Then
  Exit Do
End If
Loop
End If

Set FindAll = ResultRange

End Function

Function Union2(ParamArray Ranges() As Variant) As Range
' Union2
' A Union operation that accepts parameters that are Nothing.

Dim N As Long
Dim RR As Range
For N = LBound(Ranges) To UBound(Ranges)
  If IsObject(Ranges(n)) Then
    If Not Ranges(n) Is Nothing Then
      If TypeOf Ranges(n) Is Excel.Range Then
        If Not RR Is Nothing Then
          Set RR = Application.Union(RR, Ranges(n))
        Else
          Set RR = Ranges(n)
        End If
      End If
    End If
  End If
Next N
Set Union2 = RR
End Function
### Appendix B

**Interview guide**

<table>
<thead>
<tr>
<th>Introduction key components:</th>
<th>I would like to thank you for meeting me today. My name is Anisia Fotiadou, I am a master’s student in the field of Health Informatics. The aim of the study I am conducting is to investigate how the data deriving from the information systems of a diagnostic medical department of a public hospital can be used in order to support effective time and resource management. More specifically, I am trying to acquire new knowledge regarding the choice of different waiting time indicators and how they should be visualized and presented to different audiences. I would really appreciate your contribution in this attempt. You can read all the details regarding the project and the interview in the information sheet. This interview will not last more than an hour. I would also like to ask for your permission to audio tape this session, because I don’t want to miss any of your comments. Additionally, I would also like to ask for your permission to reveal your identity in the final report whenever it is necessary. You will have the opportunity to revise and review the relevant parts of the final report if you wish. You can ask any questions you want before and during the interview. Also remember that you can stop the interview at any time and you do not have to talk about anything that you do not want to. Please sign the consent form before beginning the session.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thank you</td>
<td></td>
</tr>
<tr>
<td>My introduction</td>
<td></td>
</tr>
<tr>
<td>Description of project and goal of the interview</td>
<td></td>
</tr>
<tr>
<td>Information sheet</td>
<td></td>
</tr>
<tr>
<td>Confidentiality</td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td></td>
</tr>
<tr>
<td>Opportunity for questions</td>
<td></td>
</tr>
<tr>
<td>Recording</td>
<td></td>
</tr>
<tr>
<td>Signing of consent form</td>
<td></td>
</tr>
<tr>
<td><strong>Main questions</strong></td>
<td></td>
</tr>
<tr>
<td>• Could you please introduce yourself? What is your position and main responsibilities?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
| **Closing key components:** | Is there anything you would like to add or any other comment you would like to make?  
I would like to remind you once more that you have the right to withdraw and that you will be given the opportunity to revise and review the relevant parts of the final report if you wish to do so.  
Thank you for your contribution and your time. |
|   |   |
| Do you think that information regarding waiting times and lists would be useful to you? |   |
| What kind of decisions are you making? |   |
| What kind of information do you need in order to make those decisions? |   |
| What kind of information is available to you at the moment? |   |
| At which point during your workflow would this information be useful to you?  
(Description of the indicators) |   |
| Are you familiar with those indicators? |   |
| Do you think that a visualization of those indicators would have beneficial effect? |   |
| If yes, what kind of? Which purposes do you think they would help serve? |   |
| Which indicator do you think would be most helpful and for what purpose? |   |
| Is a visualization of the waiting lists (number of people waiting) useful to you? In which way? |   |
| Which type of visualization do you find more helpful and why?  
(Show different kinds of visualisations: different types (e.g. bar charts, lines etc.), weekly/monthly) |   |
| Would you prefer a system that would require interaction or just pure presentation of the results? |   |
Appendix C

Choices of visualisations

During the interviews the participants were asked to choose between the following visualisations of the same indicator (which in this case is the Average O-C for all types of patients, year 2011).
Additionally, the participants were asked to choose between the representation of indicators calculated on a weekly or a monthly basis.

The following figure represents the indicators: Average O-C, 50th, 75th and 90th Percentile O-C for all types of patients, years 2011-2012.

**Weekly:**
Monthly:
Appendix D
Ethics approval

Research ethical application form
School of Computer Science and Statistics
Research Ethical Application Form

Details of the Research Project Proposal must be submitted as a separate document to include the following information:

1. Title of project
2. Purpose of project including academic rationale
3. Brief description of methods and measurements to be used
4. Participants - recruitment methods, number, age, gender, exclusion/inclusion criteria, including statistical justification for numbers of participants
5. Debriefing arrangements
6. A clear concise statement of the ethical considerations raised by the project and how you intend to deal with them
7. Cite any relevant legislation relevant to the project with the method of compliance e.g. Data Protection Act etc.

Part C

I confirm that the materials I have submitted provided a complete and accurate account of the research I propose to conduct in this context, including my assessment of the ethical ramifications.

Signed: ________________________________ Date: __________________________
Lead Researcher/student in case of project work

There is an obligation on the lead researcher to bring to the attention of the SCSS Research Ethics Committee any issues with ethical implications not clearly covered above.

Part D

If external ethical approval has been received, please complete below.

External ethical approval has been received and no further ethical approval is required from the School’s Research Ethical Committee. I have attached a copy of the external ethical approval for the School’s Research Unit.

Signed: ________________________________ Date: __________________________
Lead Researcher/student in case of project work

Part E

If the research is proposed by an undergraduate or postgraduate student, please have the below section completed.

I confirm, as an academic supervisor of this proposed research that the documents at hand are complete (i.e. each item on the submission checklist is accounted for) and are in a form that is adequate for review by the SCSS Research Ethics Committee

Signed: ________________________________ Date: __________________________
Supervisor

Completed application forms together with supporting documentation should be submitted electronically to research.ethics@scss.tcd.ie Please use TCD e-mail addresses only. When your application has been reviewed and approved by the Ethics committee hardcopies with original signatures should be submitted to the School of Computer Science & Statistics, Room F37, O’Reilly Institute, Trinity College, Dublin 2.

SCSS Research Ethics Application Form September 2011
INFORMATION SHEET FOR PARTICIPANTS

BACKGROUND OF RESEARCH: One important aspect of quality improvement in diagnostic medical imaging departments is to ensure the timely access of the patients to health care. A big amount of data deriving from different information systems (such as EHR, RIS and PACS) is being collected in each diagnostic medical department; however, in order to make it useful and meaningful, this data should be appropriately managed and presented to the right audience at the right time.

The overall aim of this study is to investigate how the data that derives from the information systems in a diagnostic imaging department can be used in order to support effective time management. This study will attempt to acquire new knowledge regarding the ways of choosing between different waiting time indicators according to the specific purposes and stakeholders of a diagnostic medical imaging department in a public hospital. The expected result is an initial design proposal for a system which will present visualization for waiting time indicators in diagnostic medical imaging department.

PROCEDURES OF THIS STUDY: This study includes the conduct of in-depth interviews where the participants will be asked to share their views and experiences regarding the choice, use and visualization of waiting time indicators. There are no risks for the participants involved in the study.

DECLARATIONS OF CONFLICTS OF INTEREST: No conflicts of interest are identified in the study.

This research is conducted as a part of a Master’s Degree in Health Informatics.
The nature of participation is voluntary. All participants have the right to withdraw and to omit individual responses without penalty.
The expected duration of the participant’s involvement is maximum 1 hour.
There are no anticipated risks for the participants.
Participants will be given the opportunity to ask questions on the research at any point.
No audio recordings will be made available to anyone other than the research/research team, nor will any such recordings be replayed in any public forum or presentation of the research. (There will be no video recording in this study.)

All direct quotations and their contextual appropriateness will be verified.

All participants are over 18 years old and are competent to provide consent.

The data will be used for scientific purposes and might be published in scientific publications.

If a participant makes illicit activities known, these will be reported to appropriate authorities.

The electronic recordings can be stopped by the participant at any time, and may at any time, even subsequent to the participation be destroyed (except in situations such as above).

Subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.

All participants will be asked to voluntarily agree to be part of this research study, though without prejudice to legal and ethical rights.

All participants are asked whether they wish to remain anonymous or not in the informed consent form.

Any direct quotes will be clarified with the participant before including them in the final report.

---

**INFORMED CONSENT FORM**

**LEAD RESEARCHER:** Anisia Fotiadou

**BACKGROUND OF RESEARCH:** This research is conducted as a part of Master’s Degree in Health Informatics.

One important aspect of quality improvement in diagnostic medical imaging departments is to ensure the timely access of the patients to health care. A big amount of data deriving from different information systems (such as EHR, RIS and PACS) is being collected in each diagnostic medical
department; however, in order to make it useful and meaningful, this data should be appropriately managed and presented to the right audience at the right time.

The overall aim of this study is to investigate how the data that derives from the information systems in a diagnostic imaging department can be used in order to support effective time management. This study will attempt to acquire new knowledge regarding the ways of choosing between different waiting time indicators according to the specific purposes and stakeholders of a diagnostic medical imaging department in a public hospital. The expected result is an initial design proposal for a system which will present visualization for waiting time indicators in diagnostic medical imaging department.

PROCEDURES OF THIS STUDY: This study includes the conduction of in-depth interviews where the participants will be asked to share their views and experiences regarding the choice, use and visualization of waiting time indicators. There are no risks for the participants involved in the study.

PUBLICATION: The study is conducted as a part of master thesis which will be presented in front of various audiences.

DECLARATION:
I am 18 years or older and am competent to provide consent.

I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications.

I understand that if I make illicit activities known, these will be reported to appropriate authorities.

I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.

I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.

I understand that any direct quotes will be clarified with me before including them in the final report.

I have received a copy of this agreement.

**Audio recording:**

- I do not agree to my interview being audio recorded.

- I do agree to my interview being audio recorded. I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above).

**Anonymity:**

- I agree that my identity might be revealed, however I wish to review the final text and provide my consent.

- I agree that my identity might be revealed and I do not require to review the final text before publication.

- I wish to remain anonymous.

**PARTICIPANT’S NAME:**

**PARTICIPANT’S SIGNATURE:**

**Date:**
Statement of investigator’s responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

RESEARCHERS CONTACT DETAILS:

INVESTIGATOR’S SIGNATURE:

Date:

Approval e-mail

Subject: RE: Research ethical approval application
From: "Research Ethics" <research-ethics@scss.tcd.ie>
Date: Thu, March 21, 2013 11:57 am
To: fotiadoa@scss.tcd.ie
Cc: "Research Ethics" <research-ethics@scss.tcd.ie>
Priority: Normal
Options: View Full Header | View Printable Version | Download this as a file | Spam | Not Spam

Dear Anisia,

Thank you for these revisions; you may now proceed with this study.

We wish you success in your research.

Kind regards

Gillian