Analysis of data flow in a Hospital Lab to aid in the investigation of the potential benefits of IT in increasing efficiency.

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Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university.

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Abstract

As sample volumes and hence workload increase rapidly from year to year in the hospital laboratory, so too do the costs. The potential IT has in decreasing the costs placed on the lab each year is as yet unknown. The question was initially addressed by composing and studying data flow diagrams for four of the main hospital laboratories in Dublin. It was restricted however to the sampling of blood for analysis, mainly the haematology lab.

The results for data flow patterns were then subsequently compared and recommendations were drawn up in terms of the potential benefits IT solutions could bring to the situation.

Through research, it was found that in previous projects involving the use of IT services in the lab environment, a reduction in turnaround time of up to 11%, while incorporating an increase in sample volume of 20%, was observed as a direct consequence of this. In one case, with the aid of IT services, there were savings of over $240,000 a year.

The research gives an insight into the manner by which hospital labs work, and also the limitations imposed. The research is an indication of the possibilities IT can have on improving the lab, and inevitably provide a more efficient and effective level of patient care.

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Chapter 1: Project Definition

1.1 Aim and Objectives of the Project:

Project Aim:

The aim of this project is to establish areas of inefficiency in the running of a clinical laboratory, while also establishing the commonalities that exist between various laboratories. This information will then be used to analyse how computers and information technology could be used to increase the efficiency of the laboratory, and inevitably provide a more effective level of patient care.

Project Objectives:

To achieve the aims above, the following key objectives have been identified:

- To establish key areas of the lab that are not efficient by drawing up detailed data flow charts of a number of hospital laboratories.
- To compare the data flow charts for all labs investigated
- To identify any issues in the data flow in the lab where efficiency may be compromised.
- To make recommendations on how IT could potentially be of benefit in solving these issues

1.2 Scope:

The term “pathology” describes clinically led diagnostic, laboratory and post mortem services, and public health and population data services based in Trusts. This includes direct patient care, interpretation and clinical liaison. The services cover a range of tests on blood and other human materials necessary for diagnosis and monitoring of a wide range of clinical conditions so that the appropriate treatment can be given, and the investigation of the reasons why people may have died and the care

of their body if they do so in hospital. However this project will concentrate specifically on only blood related testing. The scope of this project therefore includes the following pathology disciplines:

- Clinical Chemistry
- Hematology
- Immunology
- Microbiology
- Toxicology

The project will take into account all blood that comes into the pathology lab, from either external or internal source. Hence, all outpatient, inpatient, GP and external hospital samples will be taken into account.

1.3 Exclusions:

a) External lab testing (point of care testing at the patient bed side/outside the physical lab area etc)
b) Lab testing on other parts besides blood and urine
c) In-vivo diagnostics

1.4 Deliverables:

Identification of areas that directly affect the efficiency and effectiveness of work in the lab itself, by establishing work flow diagrams of the processes in use at the moment.
The project also aims to deliver a number of recommendations for how IT could be utilized to directly benefit the running of the lab.

1.5 Definitions/Abbreviation:

Lab: Hospital Laboratory

TLA: Total Lab Automation

EPR: Electronic Patient Record

IT: Information Technology

ICT: Information and Communications Technology

Phlebotomist: A phlebotomist is an individual trained to draw blood (venipuncture), either for laboratory tests or for blood donations.

Ordercoms (OCS): The implementation of 'Ordercoms' provides the functionality to allow pharmacists and medicines management technician generated orders to be send directly from the ward down to the dispensary

PTS: Pneumatic Tube System

GP: General Practitioner

HIS: Hospital Information System

LIS: Laboratory Information System

Chapter 2: Review Clinical Domain

2.1 Health Informatics

Health Information Technology has become increasingly more apparent over the past years, and has shown not only to improve quality, mainly by increasing adherence to guidelines, but also by decreasing medical error. While the limitations of paper based information management are intuitively apparent, the benefits of IT in the healthcare sector become evermore evident. In essence, information management if fundamental to healthcare delivery [1], with IT increasing its effectiveness/potential even further.

It a common human trait to be cautious about anything and everything new or unknown, with many people adapting the theory “If it ain’t broke why fix it?!” Already the priceless benefits of IT can be seen throughout the world, from real time video conferencing to real time on the spot diagnosis of a patient with leukemia. However adapting new IT systems to healthcare has proven difficult [2]in the past, with the area of IT more focused on the area of administration of finance rather than on the physical delivery of clinical care [3].

In the investigation in the study above it was found that the major effect of health IT on quality of care was its role in increasing adherence to guideline – or protocol-based care. In my experience in many work places, if protocols are paper based, there is more of a tendency for them to be either misplaced or simply not adhered to properly. If they are computerized the user has a specific obligation to adhere to it, and if they check boxes saying they have adhered to certain guidelines the onus is then specifically on them. One clinically controlled trial [4] that used computerized surveillance to aid in the early identification of “high risk patients” showed a decrease of approx 50%, from 8.2% to 4.9%, in complications due to hospitalization.

Although IT has proven priceless in many cases, if the data is not reviewed and monitored constantly it quickly becomes outdated and hence irrelevant. A study examining the use of HIT systems to facilitate in quality-

of-care measurement found that although automating the quality measurement meant it was less labour intensive, it was also found that methodological limitation affect the validity of automated quality measurement. For example: incorporating high rates of false positive results that may yield biased results. [5] Therefore it is essential to incorporate and more importantly run, quality control measures frequently, and also incorporate review and analyzing the data.

Effect on Efficiency:

Efficiency is an economic term for conditions that create the biggest possible profit with the smallest possible costs. This is an important idea in industry, since the goal of any business is to make as much money as possible and avoid wasting anything – therefore wastefulness can be described as the opposite of efficiency. It must be noted at this point that the most efficient process may be put in place but if this is not effective it is a waste of time.

Effectiveness is of particular importance in this field because health Info Technologies are tools that support the delivery of care – they do not in themselves, alter states of diseases or health [6-8]. Efficiency *is* doing things right *and* effectiveness *is* doing the right things

The main area where HIT can improve efficiency in the hospital of lab has to be computerizing the patient data, hopefully resulting in many years from now in an electronic patient record. A study into overall time to deliver care in a hospital found that there was an 11% decrease in time to deliver treatment through the use of a computerized order entry, with time decreased further with the option of sending reports directly to physician pagers. A further study found that although initially an increase was found in work rate, due to the different speed of uptake to the computer system by individuals, showed a significant increase as staff got used to the programme. [9, 10]

2.2 Clinical Laboratory

The main aim of any clinical lab is to provide accurate and efficient test results to its patents within a reasonable time frame. In order to

continuously improve the efficiency and effectiveness of work done in the lab the lab needs to evolve with technology, by spending to save and planning to grow. Any changes that are brought in must continue to improve the high quality standards for performance and accuracy of results that physicians and patients have grown to trust.

The clinical Laboratory dedicates itself to providing comprehensive, high-quality laboratory services to the communities, physicians and patients it serves.

2.2.1 Domain Description:

Pathology services deliver a complex range of services against a background of significant change and rising levels of user and public expectations. This means that significant demands are generated for consistent, high quality services across all areas of health care. In addition, an aging workforce, changing employment legislation, increasing volume demand, increasing efficiency requirements, increasing accreditation requirements, aging equipment, variations in quality standards, variations in practices and variations in costs all present significant challenges for the future which require action to be taken now.

2.2.2 Tools of Pathology

There are many different techniques frequently used in the study of the disease process and hence act as an aid to diagnosis. These are:

Gross pathology: the recognition of disease based on macroscopic examination of surgical specimens generated at the time of surgery or at autopsy.

Histology: the microscopic study of tissues. Histopathology is the science of diagnosing diseases on the basis of the histological aspect of the diseased tissues.

Cytology: the study of detached cells. Cytopathology is the science of diagnosing diseases on the basis of the cytological aspects of detached cells. The most common application of this technique is the Pap smear.

Clinical chemistry: the gathering, detection, and reporting of an incredible array of chemical measures found by the analysis of collected body samples.

Immunology: the use of specific immune markers and antibodies to aid in the diagnosis of disease.

Flow Cytometry: analysis of a process that allows for the identification of specific cells.

In our case we are restricting the investigation into the laboratory testing areas of clinical chemistry and immunology, in particular to the process specifically in relation to blood analysis, haematology.

The types of testing that gets carried out in the haematology lab are:

- Full Blood Count
- Differential
- PT / INR
- APTT /APTT Ratio
- Fibrinogen
- Thrombin Time
- D-Dimers
- Hb S Screen
- Malaria Screen

Blood specimens are collected in either micro-container tubes or evacuated collection tubes. These tubes are often colour coded for each specific test to be carried out. Urine is collected in small containers and can usually be analysed in these. Both blood and urine undergo changes once taken from the body. This change occurs more rapidly in relation to blood samples, which is particularly vulnerable to deterioration and

eventually death of all cells. Temperature is also important in keeping the samples alive, as they cannot be exposed to any extremes prior to analysis. Within the lab all samples are premixed before going through the analyser, to ensure a consistent composition.

The potential of informatics has been a major and recurring theme in the fight to modernize and maximize the services provided within the pathology laboratory. With 70% of all diagnosis and treatment dependent upon pathology investigations the role of pathology services can best be seen in terms of the information and advice it provides. [11] There is now widespread recognition that the role of pathology is to work for the patient to make the initial diagnosis, to monitor treatment and therapy efficacy, to generate data, to interpret data for clinicians and to act as an advocate for the patient in the management of their disease.

2.2.3 History of Lab Analysers

Automated haematology analysis began with simple independent cell counts. These however only took into account two parts of the blood, red blood cells and white blood cells. These counters provided the Lab with more accurate, and faster, results then manual test methods. However as the knowledge base in medicine grew so too did the technology to analyse it. Eventually the technology could break down the sample of blood into a wide variety of parameters, including platelets, haemoglobin, HCT and indices. As analysers grow in capability then the lab systems controlling all the electronic data also have to grow.

2.3 Lab Information Systems

A laboratory information system (LIS) is a module within a larger system, such as a Hospital Information System. The LIS is constantly evolving in response to changing technology and changing environmental forces, including patient expectations, physician expectations, third party payer

required agreements, legal agreements, government regulations and economic forces relating to reimbursement.

Lab computer systems have been designed and built since the mid 1960's and became effective products for specific labs in the early 1970's.The first generation systems were written in "assembly language", a set of simple but powerful machine-specific instructions that work efficiently but are knit so tightly together in their logic that they offer little opportunity for reprogramming. Even the support of these early lab systems has become unprofitable and hence many have become obsolete.

The next generation of system was written in a "high level" language that could be woven automatically into the language of the machine. The development of the computer and the operating systems added programme flexibility that allowed the programmers and then the users to take advantage of the modern machine, including background and foreground operations and the efficient organization of files. This standardisation helped vendors transfer applications from one machine to another as hardware changed.
The next generation was written in MUMPS, a language based on BASIC but developed specifically to meet the extensive text handling requirements of the medical environment. What set this apart from its predecessors was how readily it permitted the production of code, capable of creating and manipulating large and complex data files. However this compromised computer speed significantly. The next step on from this was using structured languages such as "C" and common communications orientated operating systems such as UNIX to allow multiple processors to work together as a "distributed system" in a network.

2.4 The Future of Healthcare

Major breakthroughs will – as in every market – drive the productivity and thus automation. Influences will come from the technical side as well as from diverse developments of the life science industry: pharmaceutical companies desperately need an increase in effectiveness to stay cost-effective.
Robotics and automation benefit from increased processing power, memory growth, and increased communication bandwidth up to gigabytes. This increase has spurred growth in enhanced data collection, data movement and sharing, aswell as growth in an industry centred on remote smart sensors.

There has also been an increase in personal computerized health record software. This could potentially lead to the next step in the formation of a fully integrated EPR. One such example of this software is Health ePal. This is a software program that allows the user to create and maintain family health records on a personal computer. It is a step towards a personalized family health record. The software includes forms to help the user keep all of their personal medical information together. The software is downloaded onto the user's personal computer and is password protected. It also incorporates a list of links to ranges of health information available on the web. Information regarding patient's medical history available instantaneously is priceless in terms of providing appropriate patient care.

The future potential of Health and medicine in Ireland is discussed in a report released by Engineers Ireland, [12].The focus for the future, they state, is in providing a healthcare system that moves to promoting well being, rather than merely treating the sick. The main breakthroughs are said to come not solely from looking at one area individually, but from a convergence of diverse technologies and from collaborations between different disciplines. For the future prevention rather than cure must be the objective, moving from simply treating the sick to keeping people well.

It is also essential to mainstream healthcare across all government departments, to protect and improve the population's health and well being.

As everyone is aware the future lies in both our hands and in the hands of the youths to some. So in order to keep the evolvement of the healthcare system, we have to strongly focus our resources on second level education. Hopefully increasing the numbers of students taking science and technology subjects at both 2nd and 3rd level.

If you take a look at the development over the past few years already the potential of IT becomes apparent. 10 years ago the concept of a 12yr old child using and owning their own mobile phone seemed way beyond belief, however nowadays kids as young as 9 or 10 "need" a mobile phone. Likewise in the healthcare system the idea of diagnosing a patient at their bedside using a portable glucometer, or even a portable x-ray machine, or the idea of your GP drawing blood from you in her own local GP surgery, sending the blood into the hospital, and receiving the results "hot off the press" via email all seemed way beyond belief.

The exact potential that IT can provide to the healthcare system will only be seen if there is a direct commitment in the health service to research, innovation and development.

Chapter 3 Analyzing the lab

The chief products of the lab are patient reports. Most of the steps that concern these reports involve information processing, with the exception of obtaining and preparing it that is. The emphasis should be on how data is acquired and changed in the course of laboratory operations. Laboratory systems computerise the internal information flows within laboratory groups and use this data to generate reports and for control purposes.

Rapid evolution of laboratory procedures, methodologies and equipment characterises the clinical laboratory. At present, the development of clinical laboratory science is so rapid that a vendor organisation has difficulty in absorbing, digesting and practically incorporating new enabling technologies/techniques into their vision of a global laboratory information system (LIS). The Open labs AIM project [13] found that the goal should be to provide real time quality control and self-diagnosing analytical instruments providing advice on which measures to take in case of malfunctioning, and for preventative maintenance. The typical functions of a system includes of order entry, quality control, review and edit, rerun and dilution, report generation and various utilities. However this project identified and developed additional facilities referred to as “advanced facilities”, including embedded reasoning facilities for trouble-shooting and maintenance, and external quality assessment (EQA) by external organisations. An additional benefit identified here was an interface that is a modular design whereby new instruments can be linked to the AIW by the user without the need for a software specialist.

3.1 Lab Information Management System (LIMS)

With the increasing capability of computers and analysers in the modern world, and specifically with the increased volumes of electronic data produced by automated analysers, some form of system is needed to adequately manage and control all this data. A lab management system (LIMS) is designed specifically to efficiently handle large volumes of essential data in this case. It can also aid in the quality control process, by encouraging good lab practice by standardising protocols and recordings and annotating data from every step of the workflow.

3.1.1 Case Study:

Place: Bioinformatics and Biometrics Unit,
International Crops Research Institute for the semi-arid tropics, India.

Case: A LIMS was designed and implemented here that met the exact requirements of the lab, as a moderately high throughput molecular genotyping facility. [17]

The main benefit observed in the use of the application is it leads through identical steps each time, from starting an experiment to storing the output data, standardising the entire process. Each sample is therefore handled in the same manner every time and the data stored in an identical manner.

It is also being used as a useful audit tool, in terms of quality control and also for informative reasons listing results in groups of common popularities for easier analysis. One specific function of capturing high throughput SSP (simple sequence repeat) genotyping data from the main crops of importance in the semi arid tropics, information that was always deemed highly useful but the laboratory but was simply too time consuming a process to begin to gather it all together.

Many steps of the lab are automated nowadays increasing output. These results come in several different formats from several different analysers however the LIMS can convert these all too similar formats for easy comparison.

3.2 Total Lab Automation (TLA):

A step up from a lab information management system would be to fully automate the lab itself. When properly implemented, TLA has proven to reduce overall lab expenses, enhance patient services, and address overall concerns facing labs today, such as job satisfaction, decreased length of stay and safety. Healthcare is always in the public eye, with news bulletins reporting constantly on the state of Ireland's healthcare system. Although figures released by the Health Service Executive show that the average waiting time on a hospital trolley reduced significantly in 2006, compared to the previous year, there are still up to ten people every day left waiting on a trolley for more than 24 hours. [14]

An increase in patient turnaround time, stemming directly from decrease in diagnosis, prognosis and treatment times, will hopefully lead to a decrease in the minimum hours each patient needs to be admitted to hospital and hence freeing up essential space in terms of bed allocation and also hospital resources.

What sets automation technology apart from so many other efficiency solutions are dramatic savings that it brings to the clinical lab. [15] Expenses directly related to biological and clinical diagnostics have already decreased over the past few years, despite the broader range of parameter detected and the increasingly sophisticated technologies used.

Total lab automation is a huge step for a lab to take; it involves a total overhaul of all lab equipment, and can be very expensive. In the USA for example only about 7% of the laboratories in the country are

considered to be able to benefit from TLA. A 550-bed hospital and below is not suitable for TLA, unless they have a large patient outpatient business. As a rule of thumb, experts believe a lab should be performing at least 1.5million tests per year before installing a TLA system.

Industry experts believe that a typical mid-size to large lab in the US processes 2500-3000 tests per day. With implemented automation using robotics, the lab can increase test volume by some 20%, reduce the sample turnaround times by 11%, and save about $100,000 in staff salaries. In many cases a TLA will pay for itself in three years.

3.3 Middleware:

Although TLA is impressive, it is a very expensive option and not very often feasible. Middleware is therefore a less expensive option in comparison to TLA. It aims to provide many of the same benefits as TLA, but on a smaller scale, with the intention of keeping most of the lab the same, merely by creating a more efficient location to work. It's also known as data management software or expert decision-making software. It mediates interactions between laboratory instruments and the lab information system.

How does it work?

Middleware, like many systems, uses rule-based decision processing to assist lab personnel in managing lab functions. It is an aid for improved quality also, organising exceptions and pending results for quick review. It also allows a greater review of an exact patient, allowing access to multiple instruments in real time. Middleware is designed to optimise the relationship between instruments and the LIS.

Effective Middleware can provide an efficient system that:

- Decreases turn around time
- Allows staff to focus on critical patients for rapid response to clinicians

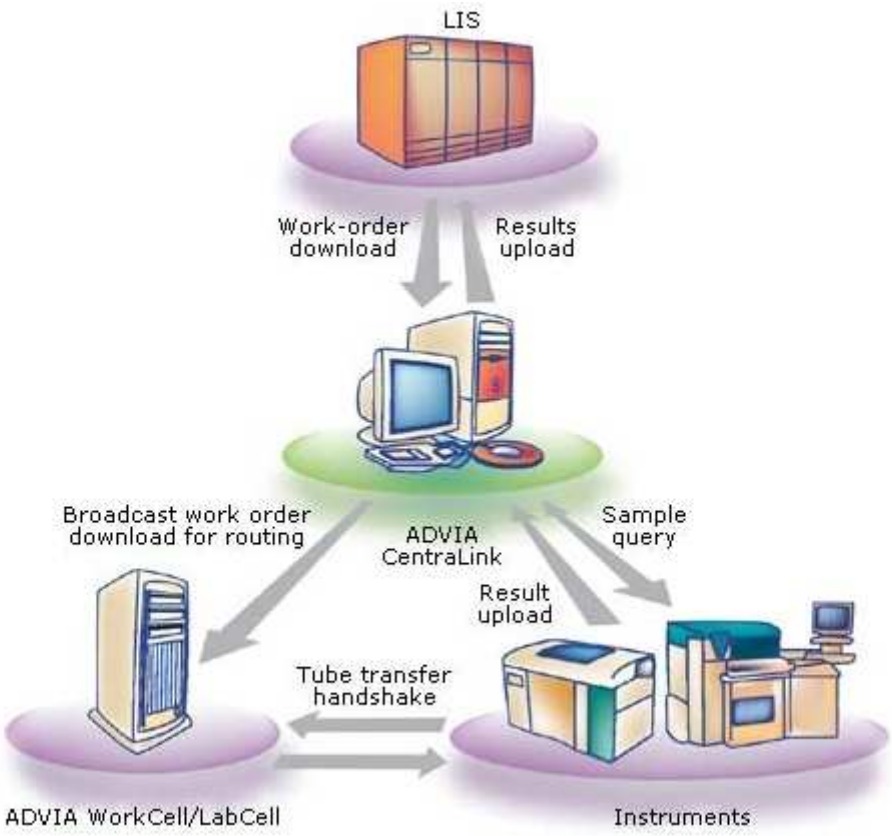
- Reduces potential for medical errors
- Improves patient safety
- Eliminates process delays to create a “queue-less” lab with efficient sample tracking

One particular product in this area is called Centralink. The idea for this product arose when it was discovered that although some Siemens lab automated systems had the capability of using 1 point of validation, the software behind the systems, called Technidata, could not deliver this particular function.

The idea was to place instruments close together and automatically route instruments between them. Specific requirements were identified by researchers, i.e. the product would have to be able to receive orders from LIS dispatch them to LAS, receive results from LAS and critically implement auto validation and rerun/reflex.

Thorough research was carried out and the first step was to implement a solution, originally called Cellnet, which was specifically for hematology units.
During the same period a review of automated products, including the ADVIA Labcell / Workcell Automation solutions, showed issues developing in terms of poor reliability and so increased costs were incurred due to system down time, making the overall system look and perform poorly.

A decision was taken for siemens to develop and offer their own Data Manager with ADVIA Automation solutions. With the feedback on the software implemented on the hematology lab units being positive, the theory and knowledge was shared with other areas of lab automation, and hence ADVIA CentraLink was born.



Some of the main features of Centralink are autoverification of normal results (in which normal results are moved out so that critical patients are prioritized for immediate intervention by the laboratory staff); processing of new orders; relaying of comments or other information to physicians; exceptional data event alerts; critical results alerts; patient misidentification alerts; delta checking; control of multiple processes on multiple instruments; organization of exceptions and pending results for quick review; and automated reflex, repeat, and add-on testing.

For example, true auto-verification, rather than just delta checking, is the result of an interaction between middleware and an LIS. Its impact on a lab can be profound. Consider that even a modest-sized hospital lab may process more than 1 million tests per year. Quality middleware can verify as much as 80–85% of those tests. Technologists only need to focus on the remaining 15–20%, which significantly reduces the lab's labour needs and leads to higher work quality for both auto- and manual verification.

It has to be noted that although feedback is still positive from the product, offering huge benefits from the basis of good information management, the uptake is still slow. It is thought that much of the organisation has stayed away from ADVIA CentraLink because of the word IT, and a lack of understanding into the potential benefits it brings to the lab. It is also a human trait to be afraid of change and this is constantly preventing the successful implementation and further development of IT in the lab.

The product is being further reviewed at the moment to hopefully incorporate a deeper level of quality control for audit purposes but the initial benefits of the installation are immediately seen, as described in the case study below.

3.3.1 Case Study:

Place: University Hospital, Barcelona, Spain.

Case:

This case details the benefits observed directly by the M.D. chief of Operation after the installation of a form of middleware software. The hospital itself is a 900-bed hospital, and is considered one of the three most important hospitals in Spain due to the sophisticated level of care.

The lab itself processes more than 4 million tests per year. After mush investigation and analysis of possible solutions, it was decided that they would invest in a middleware package from Siemens Medical Solutions.

The package, known commercially as Centralink, enables management of patient and quality control (QC) data from multiple instruments at any client workstation. It uses a single LIS and supports up to 16 instruments and up to 10 client workstations at any one time. It

also has data storage for up to 10,000 samples per connected instrument.

The main benefit reported was that many systems can be connected together, there was no need for separate software for each individual analyser – one package supports all. [18]

Additional benefits that were subsequently observed were:

- Smaller number of sample tubes needed, saving of €40,000 per year
- Reduction in the number of technicians needed, from 15 to 8, a saving of €200,000 per year.
- Decreased turnaround time – with more than 90% of samples being processed in less than one hour
- Reduced workload peaks by releasing tubes one by one, smoothing the peaks.
- Allowed the chemistry/immunochemistry lab to streamline to front end processing, less number of tubes needed for same number of tests carried out, therefore less blood need to be taken from the patient itself. The also increases the safety of the patient and reduces phlebotomist time. “The number of tubes of serum needed reduced from 3-4 to just one.”
- All these advantages helped fuel a 6% growth in lab volume, up to 4.5 million tests a year.

The market for lab automation has emerged very recently. Basically the history of lab automation parallels the development of modern drug discovery within the pharmaceutical industry.

3.4 Advanced Middleware

Advanced Middleware is a type of middleware than essentially takes on more of the work of the Lab medical scientist. It is a computer software

package which essentially works as a middleman between the individual lab analysers and the lab information system.

It is deemed more intelligent than simple middleware as it can incorporate complex rules in order to reason between different parameters. It used more complex acceptance criteria for results from analysers, and then uploads them onto the LIS. As with middleware, multiple analysers can be viewed from one workstation, further increasing the efficiency in the lab.

It main benefits are that it improves efficiencies in the lab by removing a bulk of the workload away from the staff member, and into an automated process.

A lab can work with the software to essentially tweak it to suit their application, i.e. high cancer patient cliental, high drug addicted cliental etc. It removes some of the otherwise manually verified results from the analyser, and using embedded codes allows for auto verification of these results.

This can also be the adapted to incorporate certain rules for certain group's e.g. certain acceptance criteria rules are embedded for patients from certain wards within the hospital etc.

Software like this can ease the workload on the lab staff, and allow then to get on with the everyday running of the lab instead of spending tedious hours looking at perfectly "normal" results. In the case of an unusual result, a comment can be added to rules: e.g. renal patients with low HGB – auto adds comment "check urine – ring 83764941" etc. This is handy so back up the commonly used phone service and prevent the information in the phone call being misinterpreted.

3.5 HealthLink

HealthLink is an electronic communications project funded by the Health Service Executive, and initiated in the Mater Hospital in 1995. It quickly evolved however into a national project, expanding significantly by the launch of HealthLink Online in 2003.

The objective of the HealthLink project was to implement a prototype healthcare communications network with specific reference to Primary Care Practitioners and acute Hospital and agency relationships, and data exchange. It is a web-based messaging service which allows the secure transfer of patient information over the internet. The main area of the hospital where HealthLink is used is in the clinical Laboratory. It is used in the transfer of patient lab results directly to their GP. This eliminates the delay in receiving results caused by the lab having to post the result out.

The main benefit observed when laboratories installed HealthLink was the reduction in administration resources and therefore costs. The patient blood sample remains to be sent in by courier, but all the details in relation to the sample are already with the lab via the World Wide Web. This method also reduces the risk of clinical errors, that may occur when the admin staff are manually entering in patient credentials.

The initial step when the GP wants to place an order is to generate patient information on the Host Hospital Computer System. This information is stored centrally in a SQL server database. The GP opens up their web browser, clicks on the link for HealthLink Online and then all messages specific to that username and password can be viewed. The results can then be stored, printed of exported accordingly.

However there are two major drawbacks in the HealthLink software, one being its limitation in that it cannot accommodate two-way communication, and the other being the sheer reluctance of GPs to use it.

HealthLink will be discussed further in section 5 when discussing the finding from visits to the various labs.

Chapter 4 Analysis of Information Flow

Information procedures can be represented by flow diagrams, which are only as useful as the insight they produce.

Computer systems can provide added audit trails and quality control, but these are helpful only if the checks closely follow the real situation. For example, a delta check (which assumes the lab values for a given patient will be consistent and flags those that are not, and sends them for review) should not be applied without reservations. On patients in an oncology or intensive care situation, their lab values can change dramatically due to a course of therapy or due to the expected progression of a disease. This all has to be taken into account when checking results. Hence in the real life situation there is simply no “right” or “wrong” results, everything must be dealt with in relation to its own specific situation. Error checking should discover errors in procedures not errors in assumptions.

Patient details that are recorded in the hospital, which are also utilized in the Lab are:

- Patients Surname
- Patients First Name
- Date Of Birth
- Clinical Details
- Address
- Test Required
- GP details

Optional Fields include:

- Occupation
- Marital status
- Religion

- Preferred language
- Relationships

A study into the data flow patterns in 4 of Dublin's main hospitals was carried out and evaluated. The results below show the data flow pattern individually, with discussion/comparison to follow.

NB: The only substance evaluated for lab testing was blood, so biochemistry lab in the haematology section. No urine or tissue samples were accounted for.

Data flow management in lab – blood only:

4.1 Adelaide & Meath Hosp. Tallagh, Dublin

In-house patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis. In-house patient refers to any patient that is a registered patient staying in the hospital at the time of testing, i.e. blood will be taken at bed side but a phlebotomist. This is either classed as "Urgent" or "Routine" – although it has to be noted that in the case of urgent there is actually 2 types of urgent – the type that has to be drawn from the patient immediately and sent for analysis (critical) or the case that the doctor simply writes urgent as a formality and in reality there request is simply to have the results for analysis the following day at morning rounds. The exact flow is as follows:

1. Phlebotomist draws blood from patient immediately.
2. Request for specific tests is the then added to the ordercoms system.
3. Barcode generated and attached to each vile of blood

4. Blood sample and request form sent via vacuum system to the lab.
5. Upon arrival at central lab the tube is then opened by staff and patient name on request matched with that on scanned barcode.
6. Each vile is then sent separately to each section necessary for analysis, depending on tests requested.
7. If barcodes are already attached then these are checked again with patient name and number. The urgent samples are sent for immediate analysis and the non-urgent are sent into a waiting queue and analysed in order.
8. The less tedious part of this whole process is the actual analysers. Once the blood has been spun (approx 5 mins for this) then in less than 45 mins the patient result will be available on the ward to the staff via the ordercoms system. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
9. A paper report is also generated at this stage. All paper reports are gathered and quick review carried out by lab manager. These are then sent back to the ward to be added to the patients file.

The main drawbacks already visible at this stage is that the actually analysing of the blood sample itself isn’t the most time consuming or tedious part, it’s the logging of the patient details that’s key.
Small other delays include staff not looking in the vacuum system for deliveries, sometimes blood waiting up to 10 mins there. The speed of the vacuum system and availability of canisters are also found to cause delays however this problem is not trivial.
Also as in part 9 above, it is found that approx 20% of the paper based results generated never actually make it into the patients file. The need for this service needs to be reviewed as its is both time and resource consuming daily.

Out- patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis.
These are all classed as “Routine”. The exact flow is as follows:

1. Blood taken from patient by GP or in “outpatients” clinic by phlebotomist. The racks on which the bloods are stored are physically transferred by human to the lab for testing. The first striking observation is that the transfer over to the lab of the material in not instantaneous. As each tray can hold up to 40 samples at once, the phlebotomist usually waits till it’s quite full before transferring to the lab for analysis. This could mean a delay of afew hours from time blood enters the outpatients until it is transferred to the lab and starts the analysing process.
2. Upon arrival at the lab, through the main/common area, the blood viles are all individually checked in comparison with the request for, to ensure name, age, address etc are identical.
3. The bloods are then separated into each specific area to be transferred to the necessary labs, i.e. biochemistry lab is separate to microbiology lab etc. These trays also may take time before they are physically moved to the necessary lab, due to staff waiting for a full tray before transportation.
4. The viles then arrive on trays in the individual lab. Checked again to ensure name, age, address etc are identical.
5. Request for specific tests is then added to the ordercoms system.
6. Barcode generated and attached to each vile of blood.
7. The samples are then sent into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old.
8. The less tedious part of this whole process is the actual analysers. Once spun, in less than 45 mins the patient result will be available for print out and to be sent back to the outpatient chart/GP via post. “Normal” results are automatically approved by

the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.

9. A paper report is generated at this stage. All paper reports are gathered and quick review carried out by lab manager. These are then sent back to the patients file to a sorting office to be eventually sent out to the GP.

The main drawbacks already visible at this stage is that the actually analysing of the blood sample itself isn’t the most time consuming or tedious part, it’s the logging of the patient details that’s key.

Small other delays include staff not looking in the vacuum system for deliveries, sometimes blood waiting up to 10 mins there. The speed of the vacuum system and availability of canisters are also found to cause delays however this problem is not trivial.

Also as in part 9 above, it is found that approx 20% of the paper based results generated never actually make it into the patients file (Ref. 1). The need for this service needs to be reviewed as it is both time and resource consuming daily.

Figure 1: Data flow chart for Outpatients required to give blood for analysis.

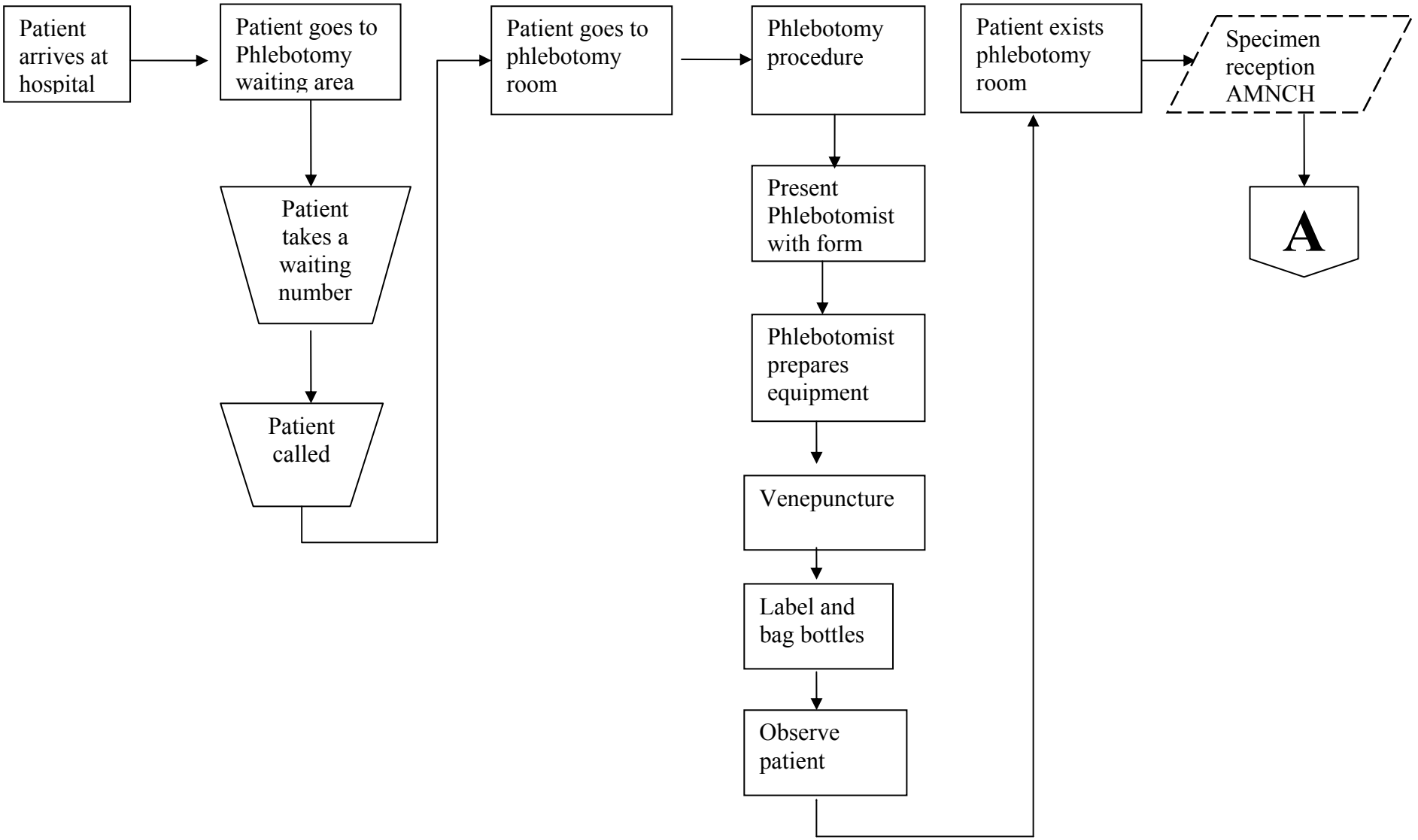


Figure 2: Data flow at Specimen Reception (Non OCS registered)

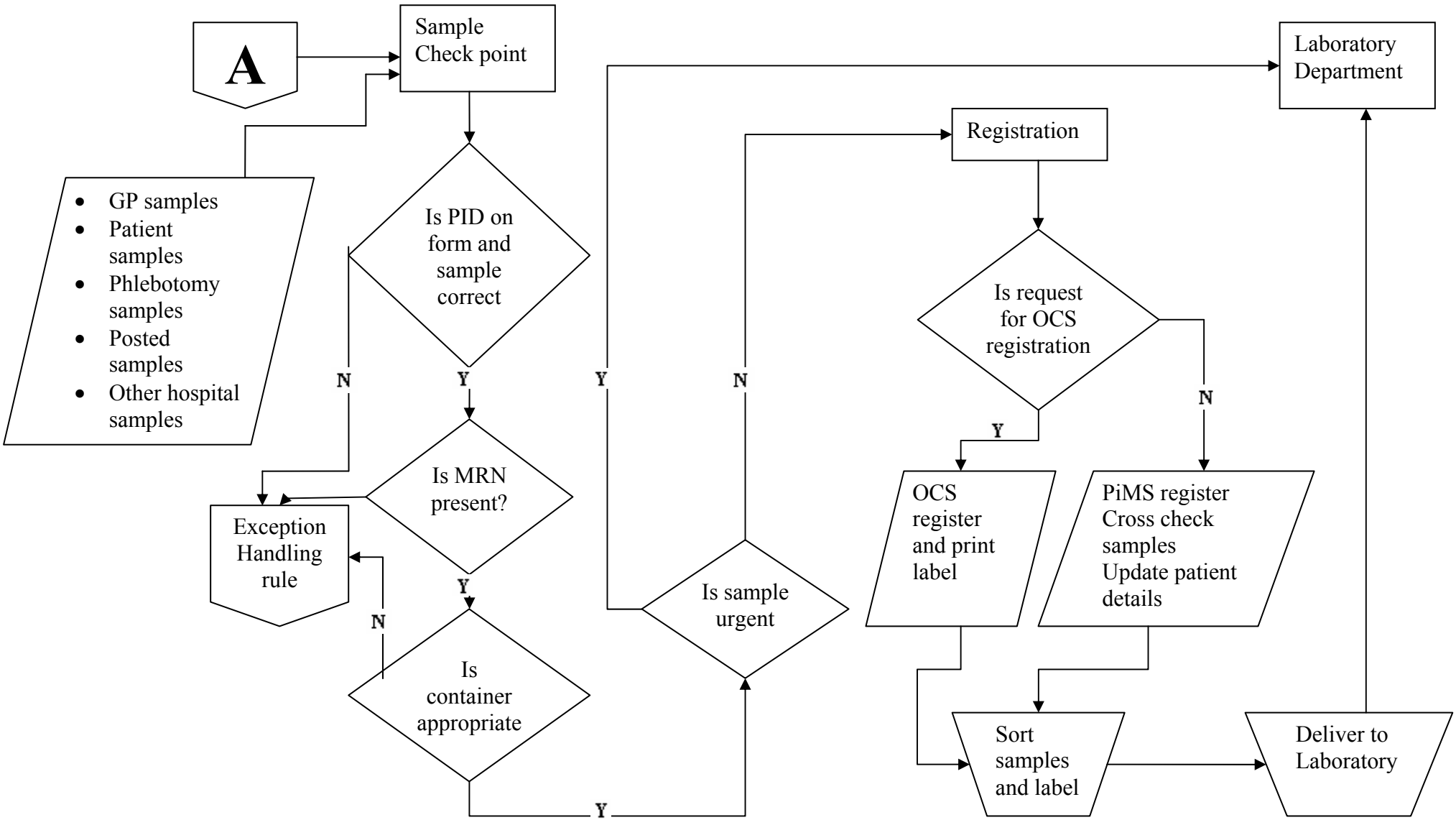


Figure 3: Ordercoms system registered samples in Laboratory

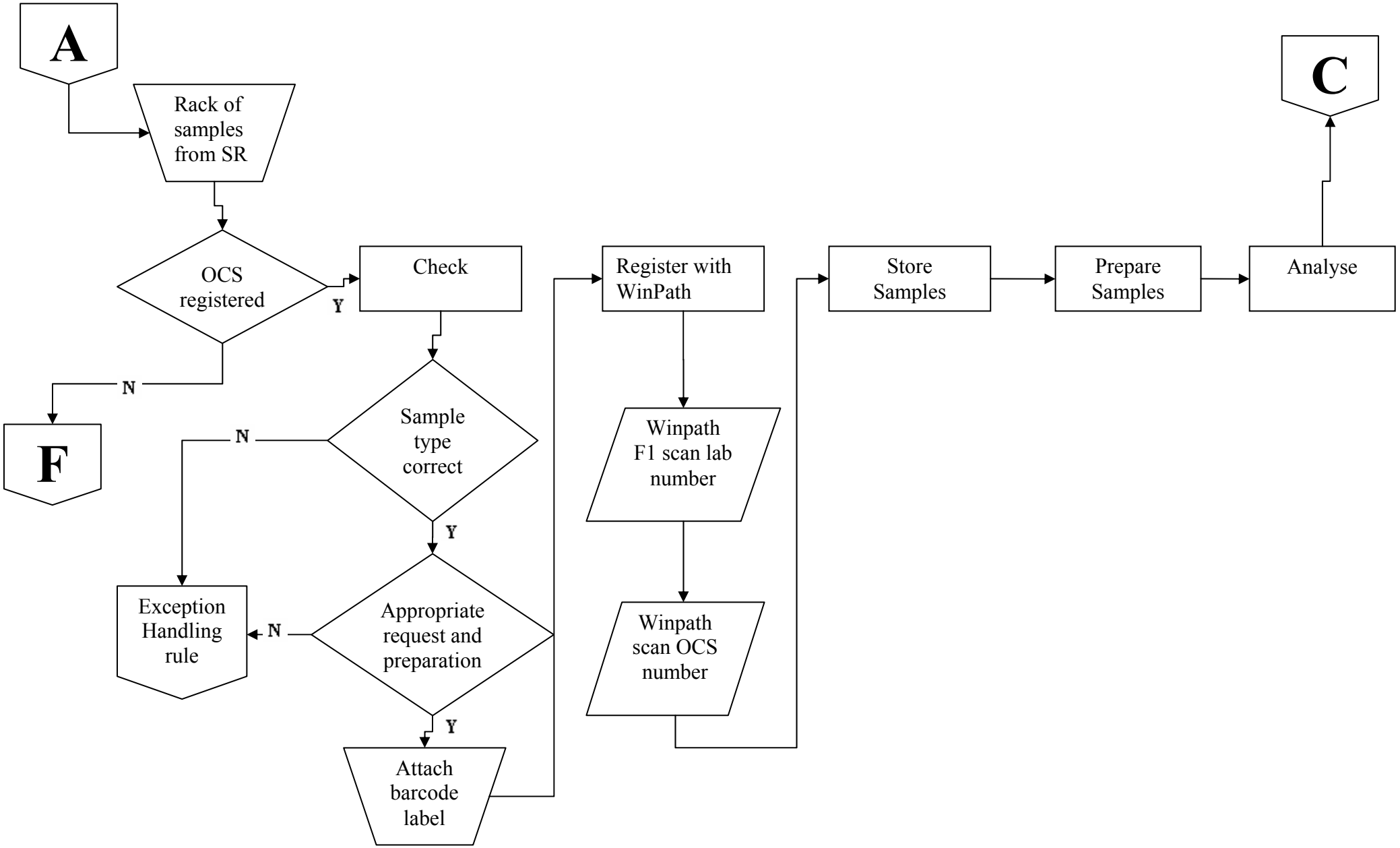


Figure 4: Samples registered for analysis in hematology lab

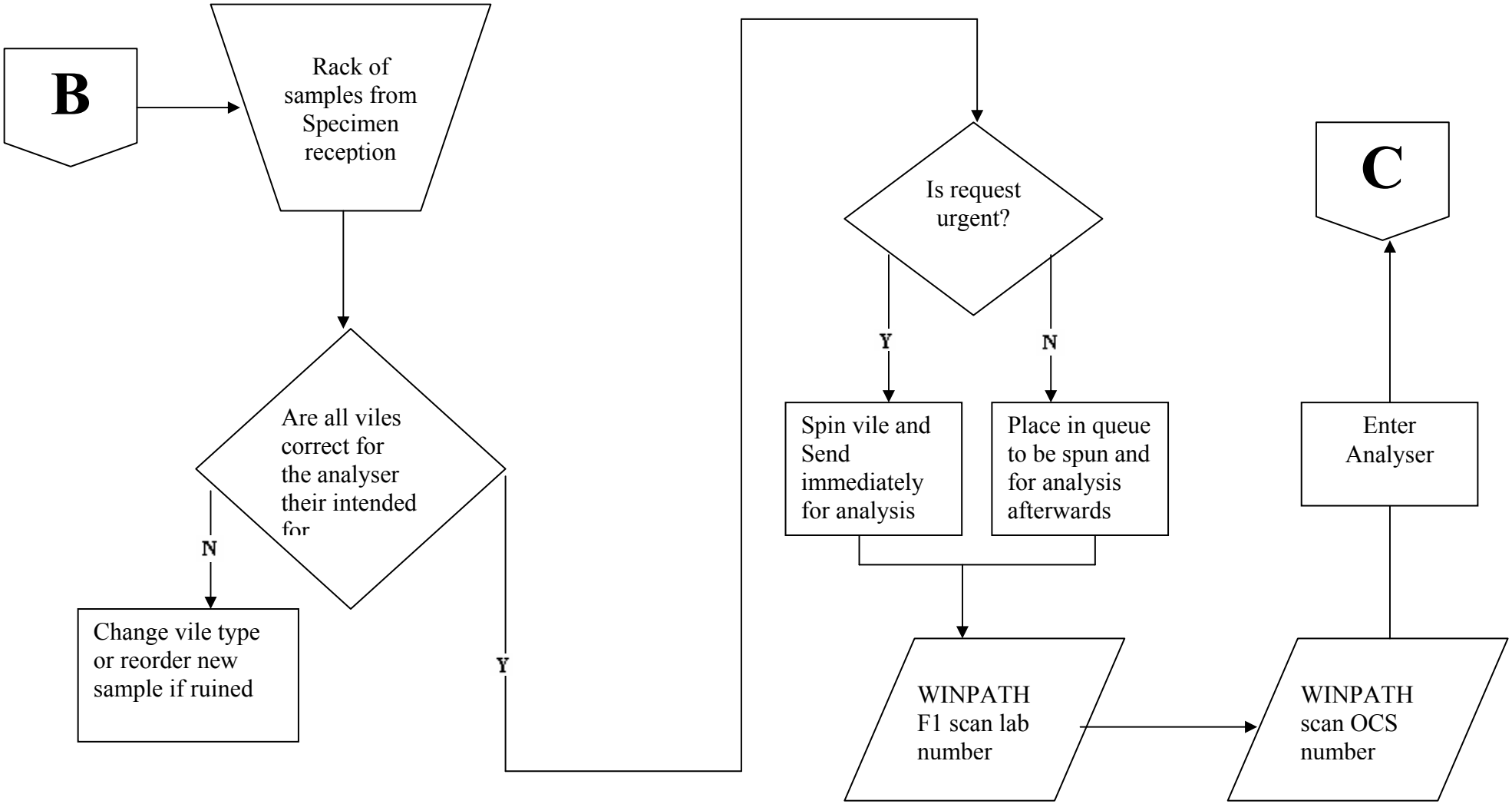
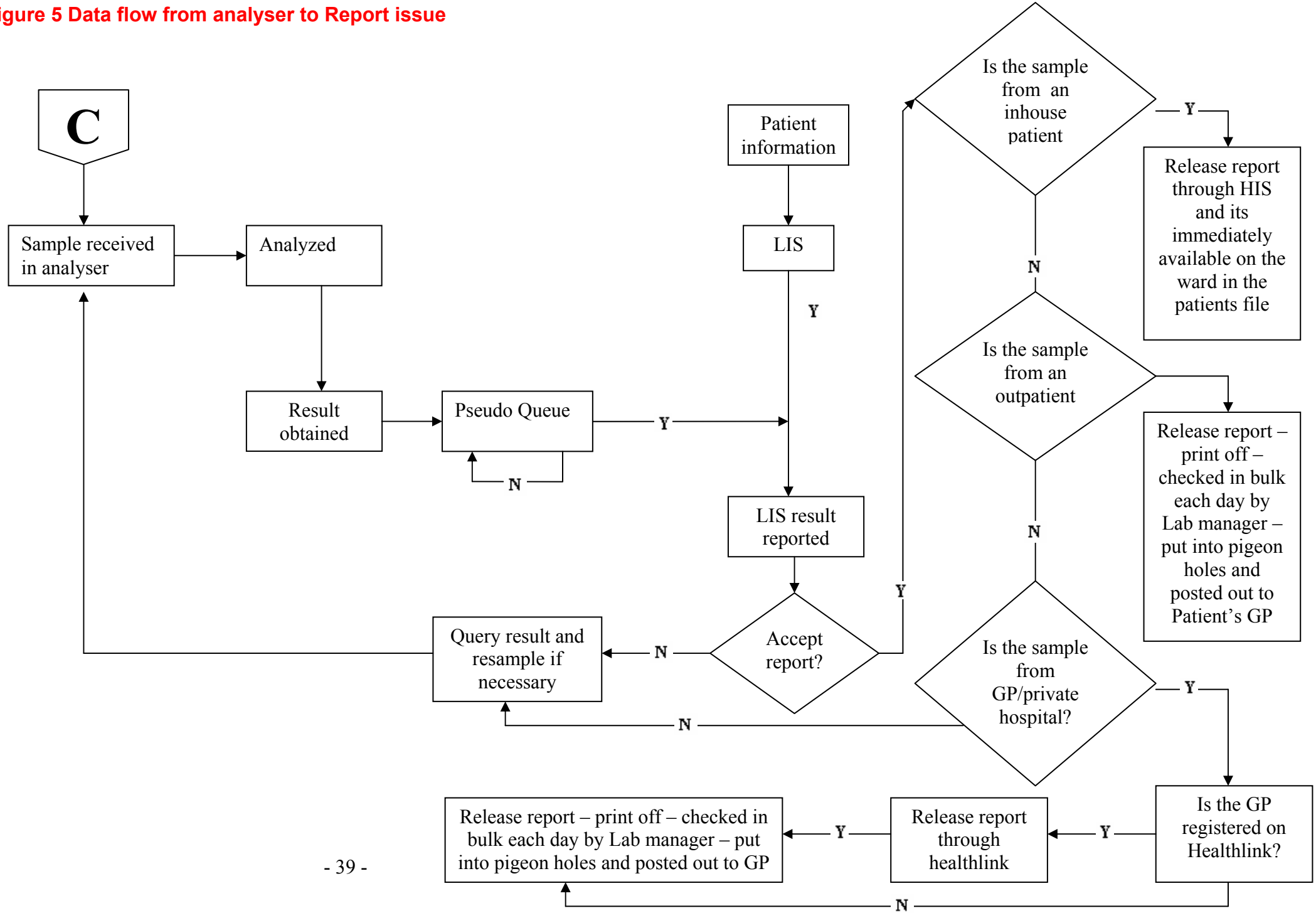


Figure 5 Data flow from analyser to Report issue



4.2 Mater Hospital, Dublin.

In-house patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis. In-house patient refers to any patient that is a registered patient staying in the hospital at the time of testing, i.e. blood will be taken at bed side but a phlebotomist.

This is either classed as “Urgent” or “Routine” – although it has to be noted that in the case of urgent there is actually 2 types of urgent – the type that has to be drawn from the patient immediately and sent for analysis (critical) or the case that the doctor simply writes urgent as a formality and in reality there request is simply to have the results for analysis the following day at morning rounds. The exact flow is as follows:

1. Phlebotomist draws blood from patient immediately.
2. Request for specific tests is the then added to the ordercoms system.
3. Barcode generated and attached to each vile of blood
4. Blood sample and request form sent via vacuum system to the lab.
5. Upon arrival at central lab the tube is then opened by staff and patient name on request matched with that on scanned barcode.
6. Each vile is then sent separately to each section necessary for analysis, depending on tests requested.
7. If barcodes are already attached then these are checked again with patient name and number. The urgent samples are sent for immediate analysis and the non-urgent are sent into a waiting queue and analysed in order.
8. The less tedious part of this whole process is the actual analysers. Once the blood has been spun (approx 5 mins for this) then in less than 45 mins the patient result will be available on the ward to the staff via the ordercoms system. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
9. A paper report is also generated at this stage. All paper reports are gathered and quick review carried out by lab manager. These are then sent back to the ward to be added to the patients file.

Out- patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis.

These are all classed as “Routine”. In the mater there is two different type of samples that come in, outpatients that are sent to the hospital outpatient clinic to get blood drawn, and blood sent in already drawn by a GP. The flow of the blood from the GP is as follows:

1. Blood taken from patient by GP. The GP has a software package called HealthLink, as discussed earlier. The request is put into the system and a copy of the request printed by the GP and put into the bag with the blood.
2. The courier is sent around to all the GP surgeries that have requested blood sampling and delivered everyday to the hospital between 11-2.
3. The racks arrive at the sample reception.
4. The bloods are then separated into each specific area to be transferred to the necessary labs, i.e. biochemistry lab is separate to microbiology lab etc, and are manually entered onto the HIS system.
5. The viles then arrive on trays in the individual lab. Checked again to ensure name, age, address etc are identical.
6. Barcode generated and attached to each vile of blood.
7. The samples are then sent into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old.
8. The less tedious part of this whole process is the actual analysers. Once spun, in less than 45 mins the patient result will be available for print out and to be sent back to the outpatient chart/GP via post. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
9. An electronic report is generated and sent back to the GP (once reviewed and signed off at the lab) through the HealthLink software. A paper report is also generated at this stage and kept on file.

The flow of the blood from the outpatient’s clinic is as follows:

1. The in-house outpatient blood samples are done in a similar fashion, except the person is physically in the hospital. The receptionist takes the patients details as they arrive at the phlebotomy clinic and enters their details onto the HIS. A barcode is generated and printed inside at the nurse's station where the blood will be drawn.
2. The patient is then called and asked to verify their details, name date of birth and address.
3. Blood is drawn and then put into the bin for the test requested, e.g. the specific lab it is to go to.
4. Blood is sent up to the lab by courier at regular intervals during the day.
5. The samples are then sent, like all other samples, into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old.
6. The less tedious part of this whole process is the actual analysers. Once spun, in less than 45 mins the patient result will be available for print out and to be sent back to the outpatient chart/GP via post. "Normal" results are automatically approved by the analysers and only "questionable" results are triggered for intervention from the lab technician for analysis.
7. A paper report is generated and sent back to the GP/Doctor (once reviewed and signed off at the lab) who requested the test. An electronic report is also generated at this stage and is kept under the patients HIS number for a given length of time.

Figure 1: Data flow chart for Outpatients required to give blood for analysis.

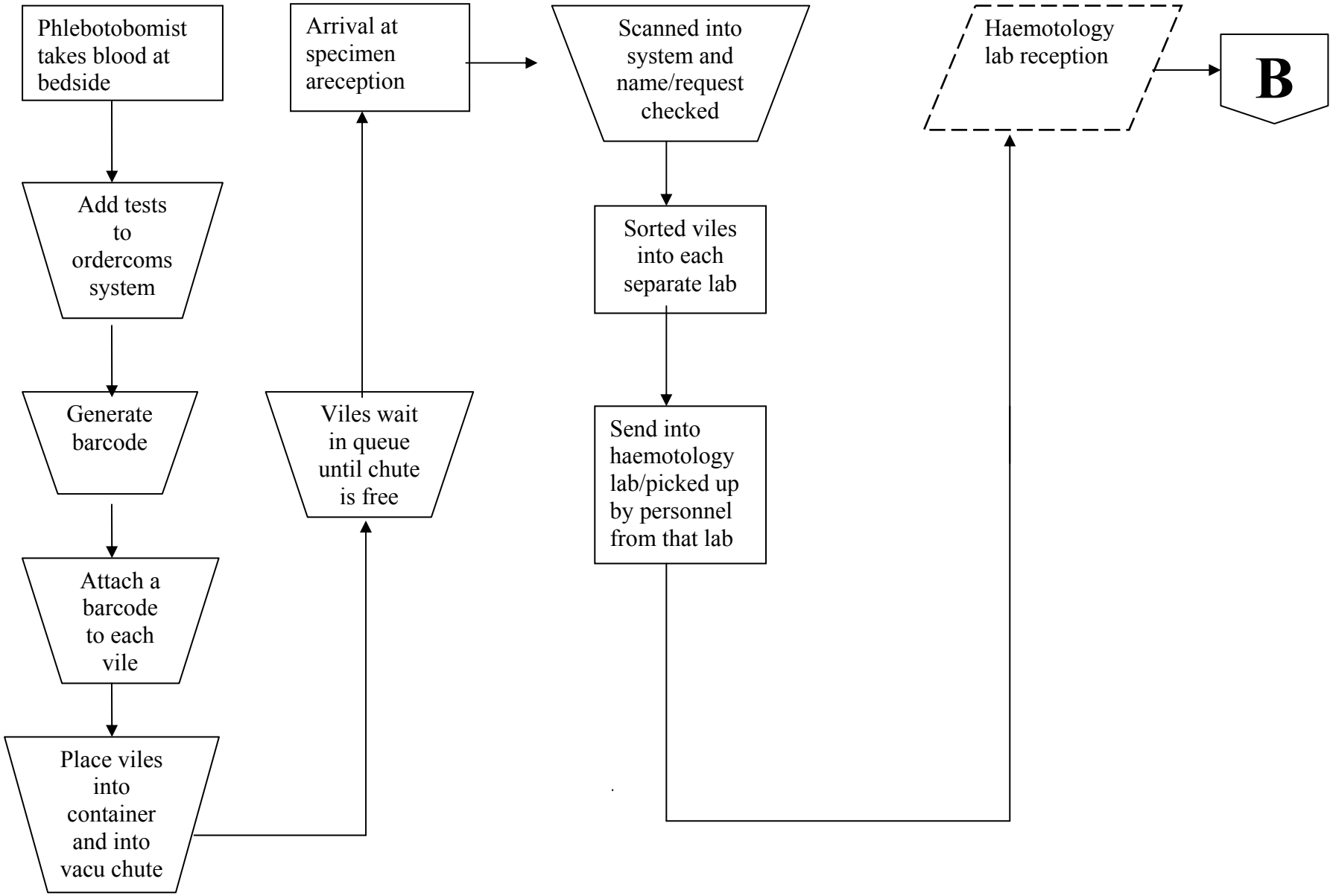


Figure 2a: Data flow for Outpatients required to give blood in hospital

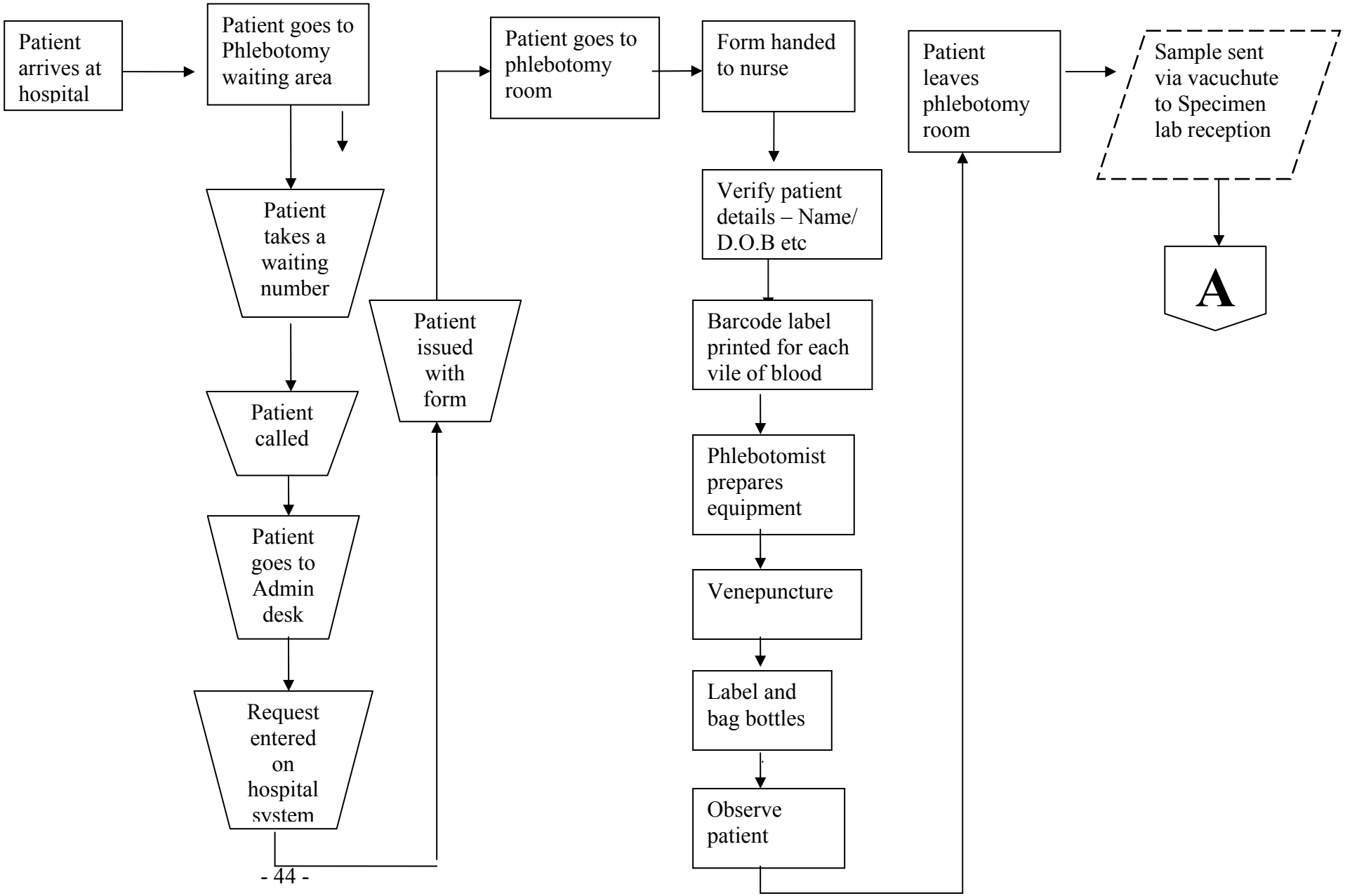


Figure 2b: Data flow for GP's blood samples analysed in hospital

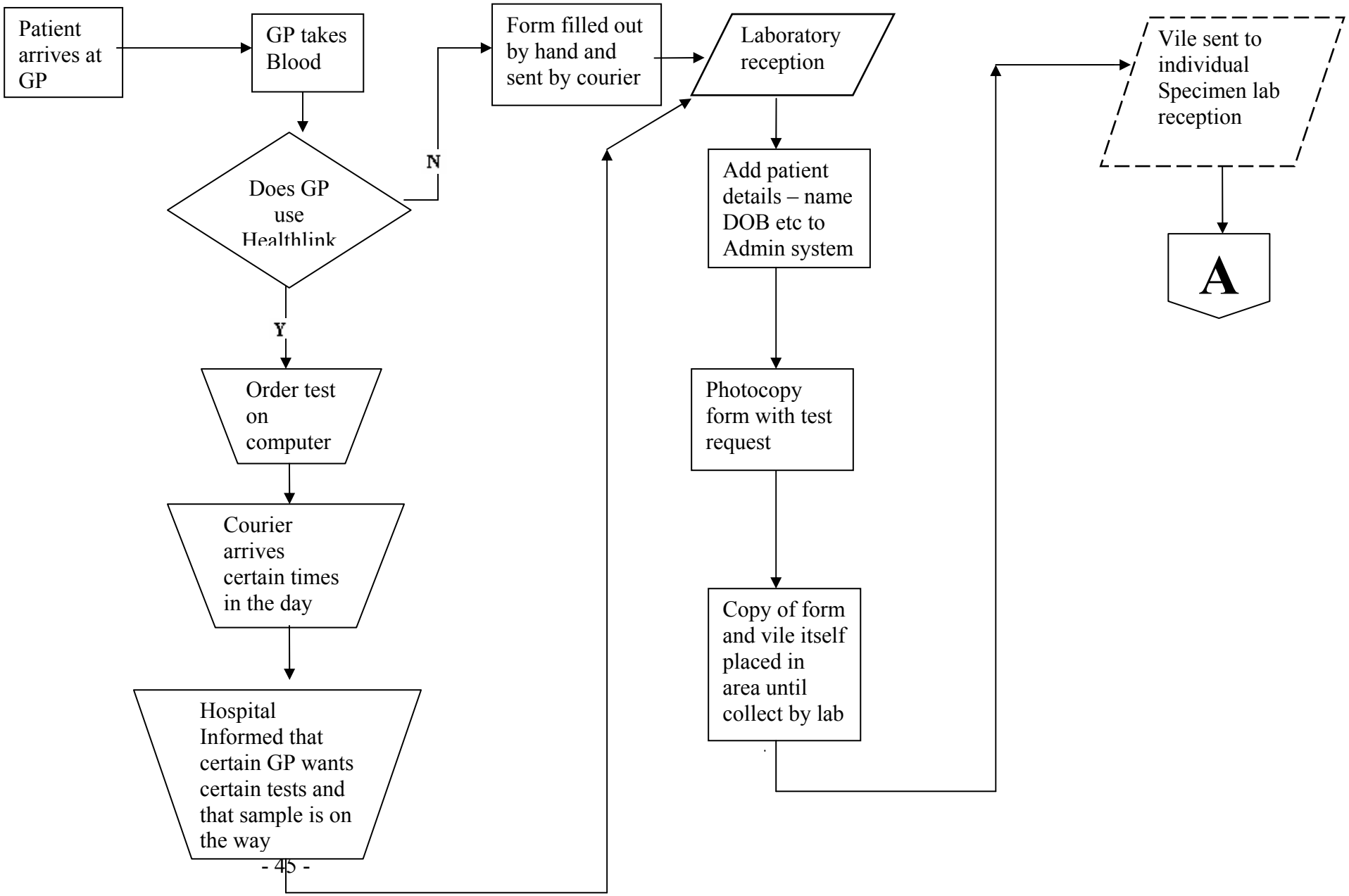


Figure 3: Data flow at specimen reception (Non OCS registered)

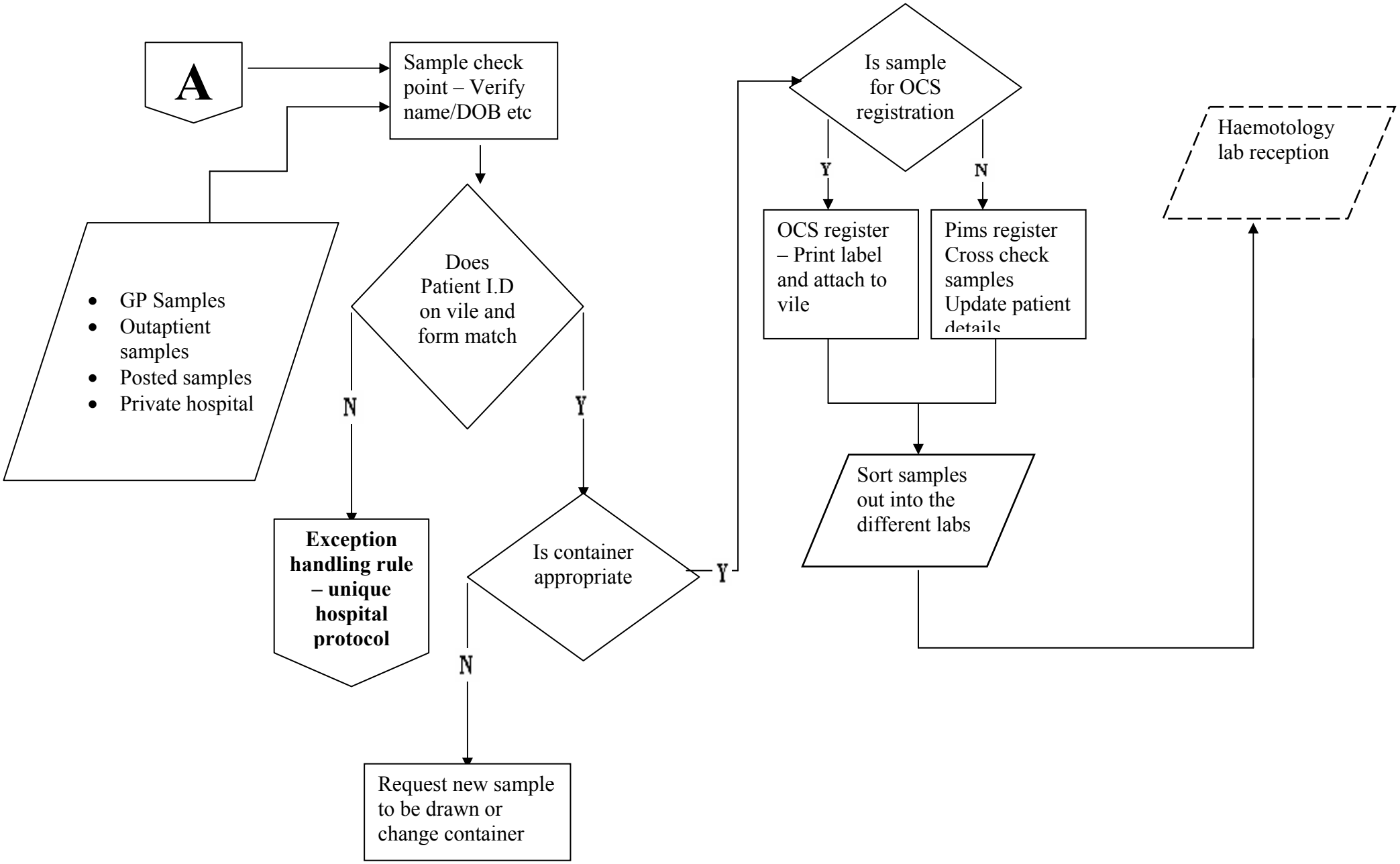


Figure 4: Samples registered for analysis in hematology lab

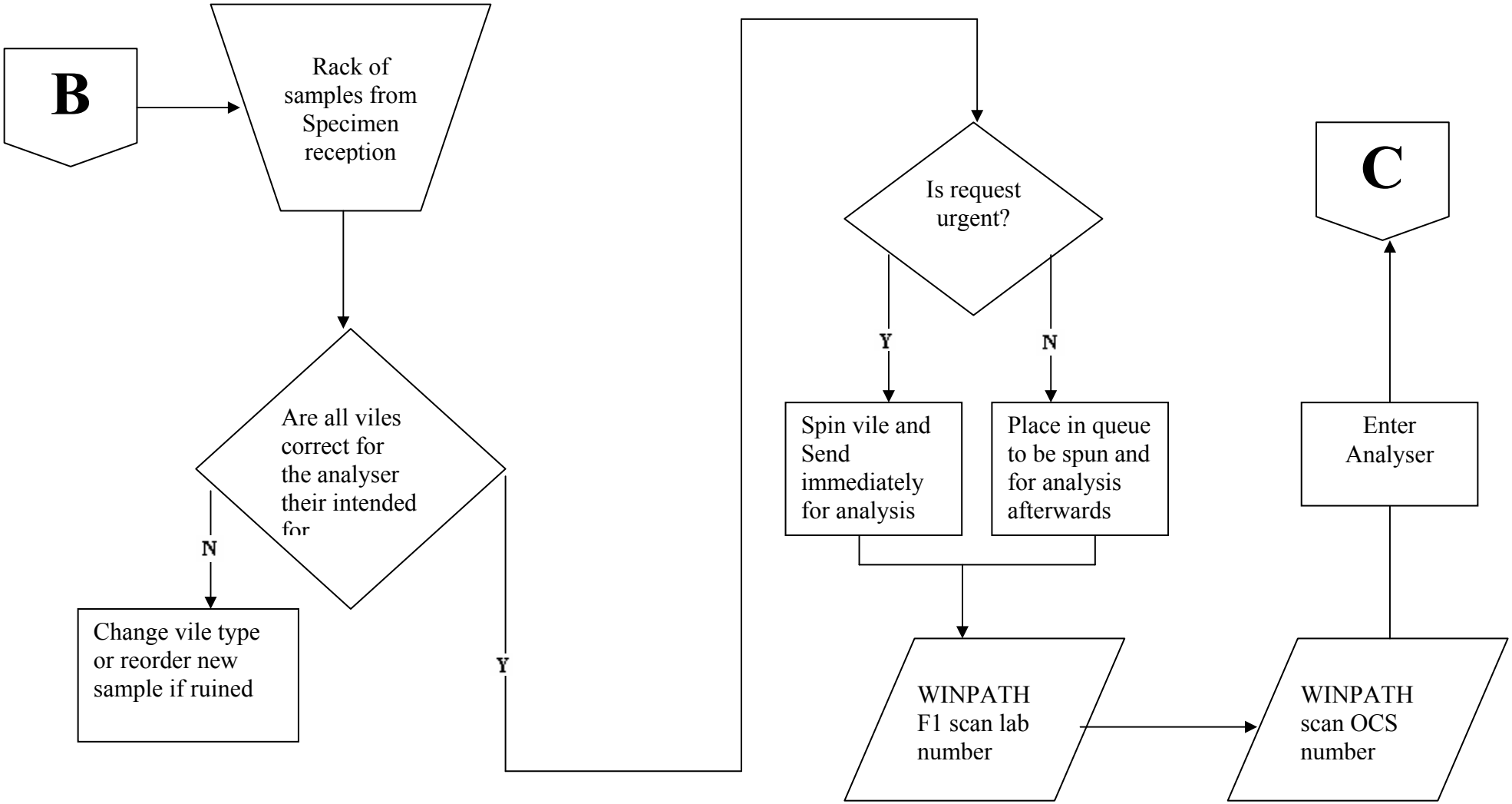
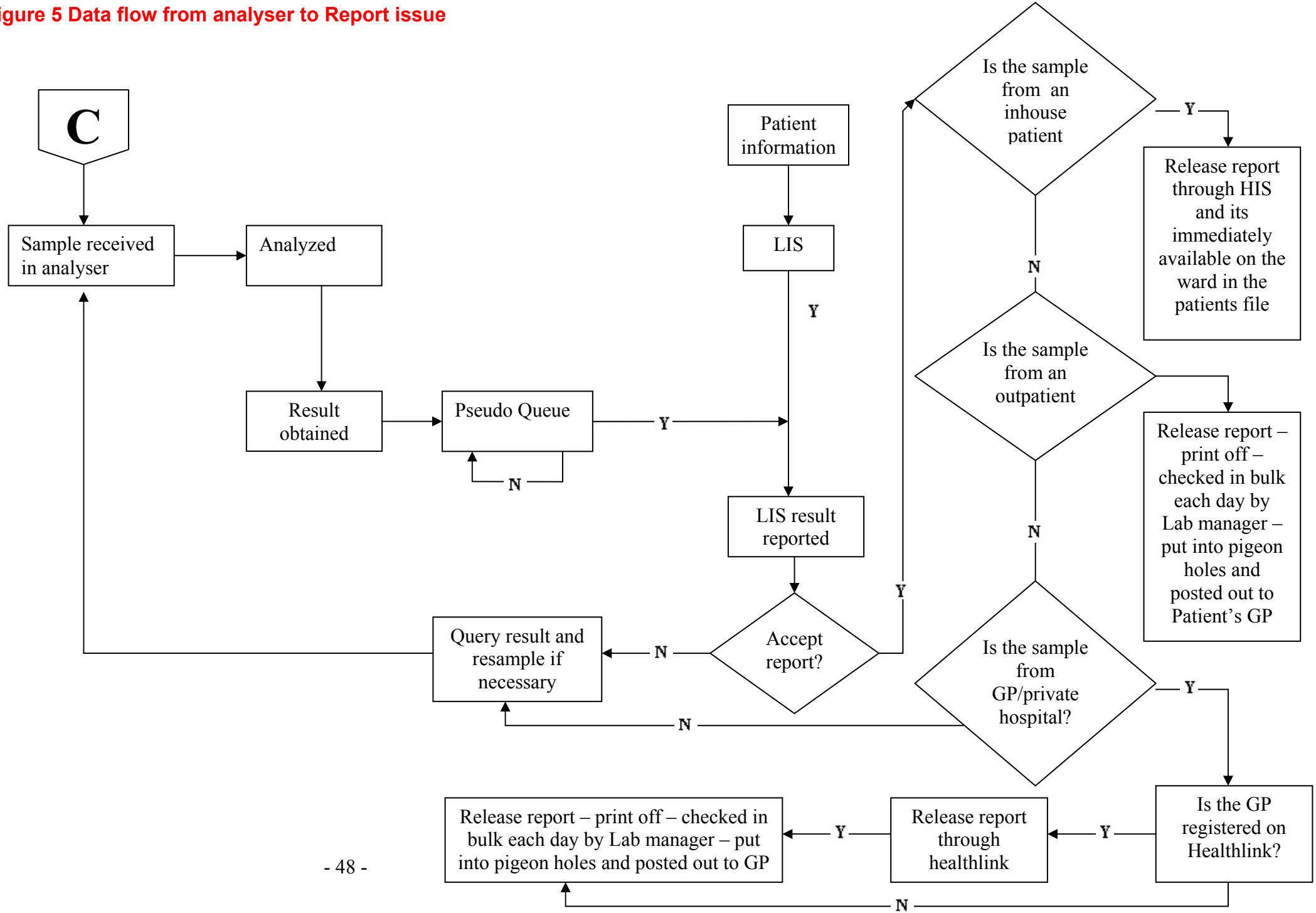


Figure 5 Data flow from analyser to Report issue



4.3 St.James' hospital, Dublin

In-house patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis. In-house patient refers to any patient that is a registered patient staying in the hospital at the time of testing, i.e. blood will be taken at bed side but a phlebotomist.

This is either classed as "Urgent" or "Routine" – although it has to be noted that in the case of urgent there is actually 2 types of urgent – the type that has to be drawn from the patient immediately and sent for analysis (critical) or the case that the doctor simply writes urgent as a formality and in reality there request is simply to have the results for analysis the following day at morning rounds. The exact flow is as follows:

1. Phlebotomist draws blood from patient immediately.
2. Request for specific tests is the then added to the ordering system.
3. Barcode generated and attached to each vile of blood
4. Blood sample and request form sent via vacuum system to the lab.
5. Upon arrival at central lab the vacuum container with the tubes inside is then opened by staff and sorted into buckets as per lab.
6. Each vile is then sent separately to each section necessary for analysis, depending on tests requested.
7. Patient details on the vile are then checked again with those on the HIS system.
8. A specific label for the biochemistry haematology lab is then added to the vile. This is then scanned in and linked electronically to the patient details from the HIS using the Telipath system. These details are now all available on the LIS.
9. The urgent samples are marked clearly in red and sent for immediate analysis. The non-urgent, or routine, samples are marked clearly in white and sent into a waiting queue and analysed in order.
10. Specimen is decapped manually, which is a very time consuming process.

11. On routine samples there is approx a back log of 500 samples at any one time.
12. The less tedious part of this whole process is the actual analysers. Once the blood has been spun (approx 5 mins for this) then in less than 45 mins the patient result will be available on the ward to the staff via the ordercoms system.
13. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
14. No paper report is generated anymore for in-house patients, as thorough research on behalf of the lab showed that only approx 20% of all reports printed off actually made it physically into the patients file. The report is accepted by the Chief Medical Scientist and appears automatically on the HIS available for the staff to read on the ward.

The main drawbacks already visible at this stage is that the actually analysing of the blood sample itself isn’t the most time consuming or tedious part, it’s the logging of the patient details that’s key.
Further delays are seen when a sample does not analyse properly and a rerun in necessary. This is a highly costly part of the everyday running of the lab.

Out- patient:
The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis.
These are all classed as “Routine”. In St.James’s hospital there are two different types of samples that come in, outpatients that are sent to the hospital outpatient clinic to get blood drawn, and blood sent in already drawn by a GP. The flow of the blood from the GP is as follows:

1. Blood taken from patient by GP. The GP has a software package called HealthLink, as discussed earlier. The request is put into the system and a copy of the request printed by the GP and put into the bag with the blood.

2. The courier is sent around to all the GP surgeries that have requested blood sampling and delivered everyday to the hospital between 11-2.
3. The racks arrive at the sample reception.
4. The bloods are then separated into each specific area to be transferred to the necessary labs, i.e. biochemistry lab is separate to microbiology lab etc.
5. The form with the sample is then photocopied and a copy sent with each vile to the relevant lab.
6. When the viles arrive in the lab the patient details are not entered on the system at this stage. A lab barcode is issued for the vile and this is attached to the form aswel.
7. The form is then sent into admin area when clerical staffs adds the patient details to the computer and link it electronically to the vile for analysis by scanning the replica barcode on the page.
8. The viles then arrive on trays in the individual lab. Checked again to ensure name, age, address etc are identical.
9. The samples are then sent into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old.
10. The less tedious part of this whole process is the actual analysers. Once spun, in less than 45 mins the patient result will be available for print out and to be sent back to the outpatient chart/GP via post.
11. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
12. All accepted reports are then sent from the analyser to the LIS.
13. If the GP does not use HealthLink then the report is printed, signed off by the lab manager and sorted into pigeon holes as per GP surname. These are then sent out by post to arrive with the GP in 2-3 working days.
14. An electronic report is generated and sent back to the GP (once reviewed and signed off at the lab) through the HealthLink software immediately. A paper report is also generated at this stage and sent out.
15. The patient request form from the GP is stored for 6months and then discarded.

The flow of the blood from the outpatient's clinic is as follows:

1. The in-house outpatient blood samples are done in a similar fashion, except the person is physically in the hospital.
2. The receptionist takes the patients details as they arrive at the phlebotomy clinic and enters their details onto the HIS. They then wait in turn to be called into the room for the procedure to take place.
3. A barcode is generated on a form and printed inside at the nurse's station where the blood will be drawn.
4. The patient is then called and asked to verify their details, name date of birth and address.
5. Blood is drawn and then put into the bin for the test requested, e.g. the specific lab it is to go to.
6. Blood is sent up to the lab by courier at regular intervals during the day.
7. At each individual lab reception the vile is then rescanned to verify patient details. Lab barcode is generated and linked electronically to the patient details through a scanner.
8. The samples are then sent, like all other samples, into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old.
9. The less tedious part of this whole process is the actual analysers. Once spun, in less than 45 mins the patient result will be available for print out and to be sent back to the outpatient chart/GP via post.
10. "Normal" results are automatically approved by the analysers and only "questionable" results are triggered for intervention from the lab technician for analysis.
11. All accepted reports are then sent from the analyser to the LIS.
12. A paper report is generated and sent back to the GP/Doctor (once reviewed and signed off at the lab) who requested the test.

Figure 1: Data flow chart for Outpatients required to give blood for analysis.

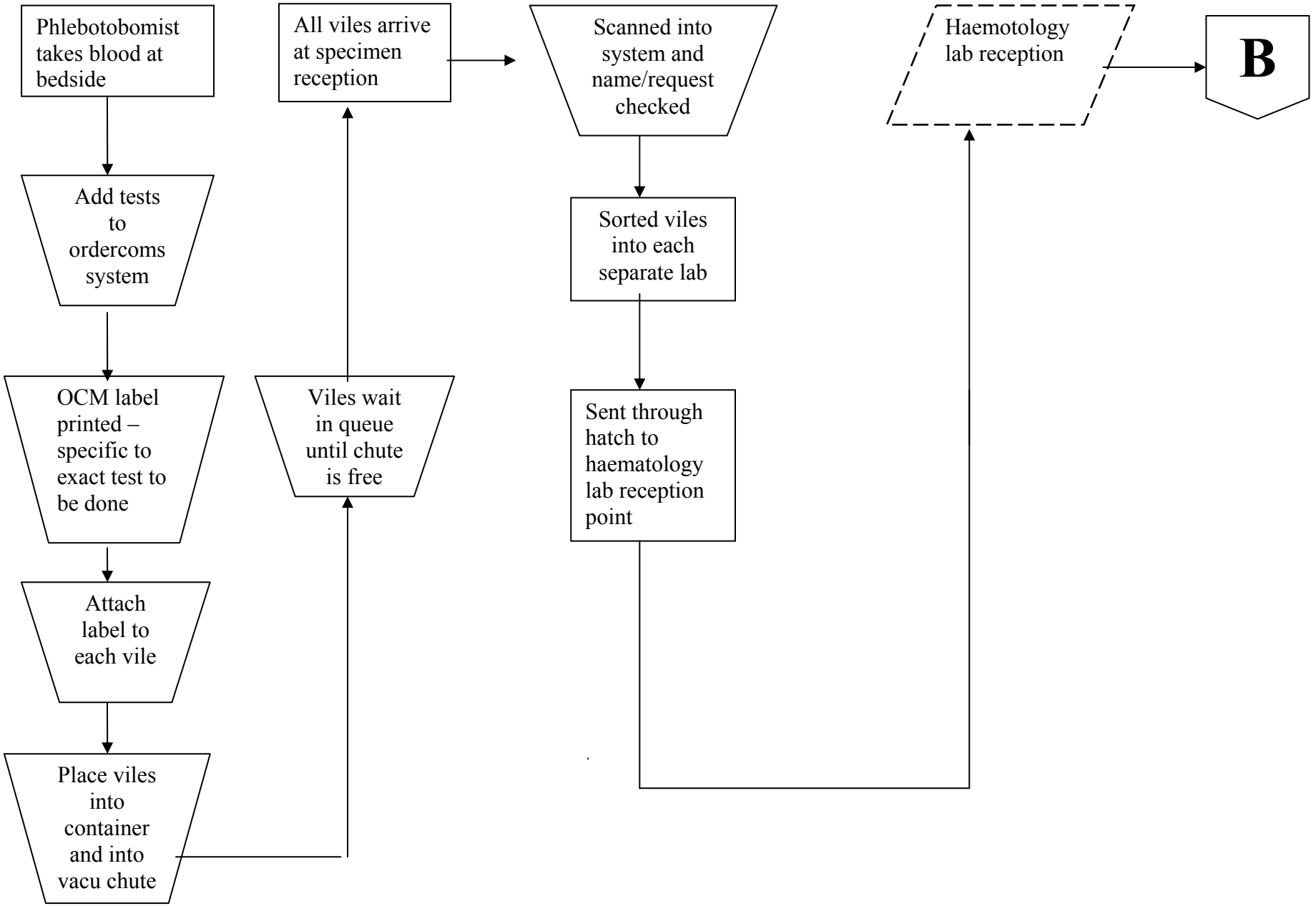


Figure 2a: Data flow for Outpatients required to give blood in hospital

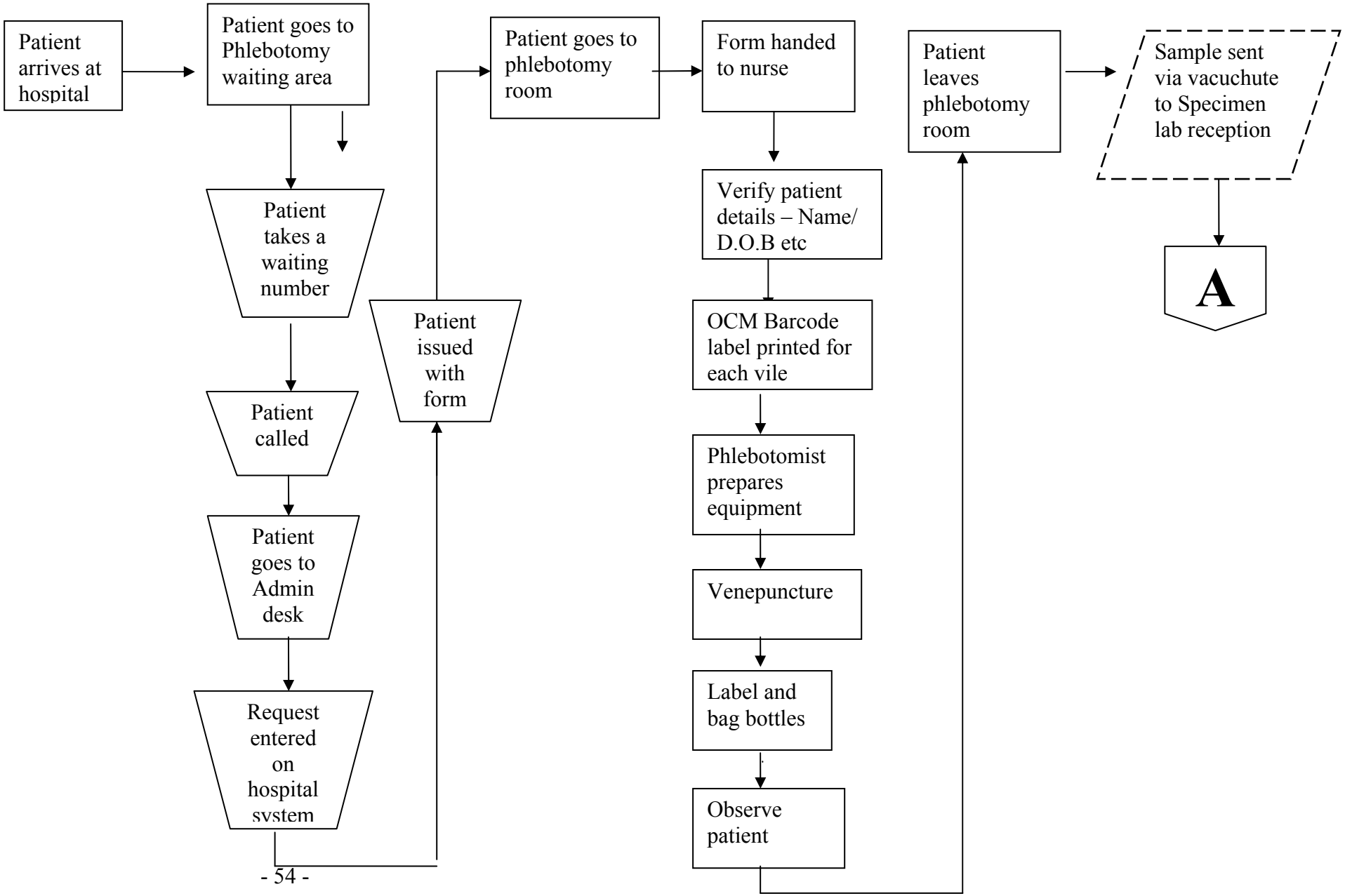


Figure 2b: Data flow for GP's blood samples analysed in hospital

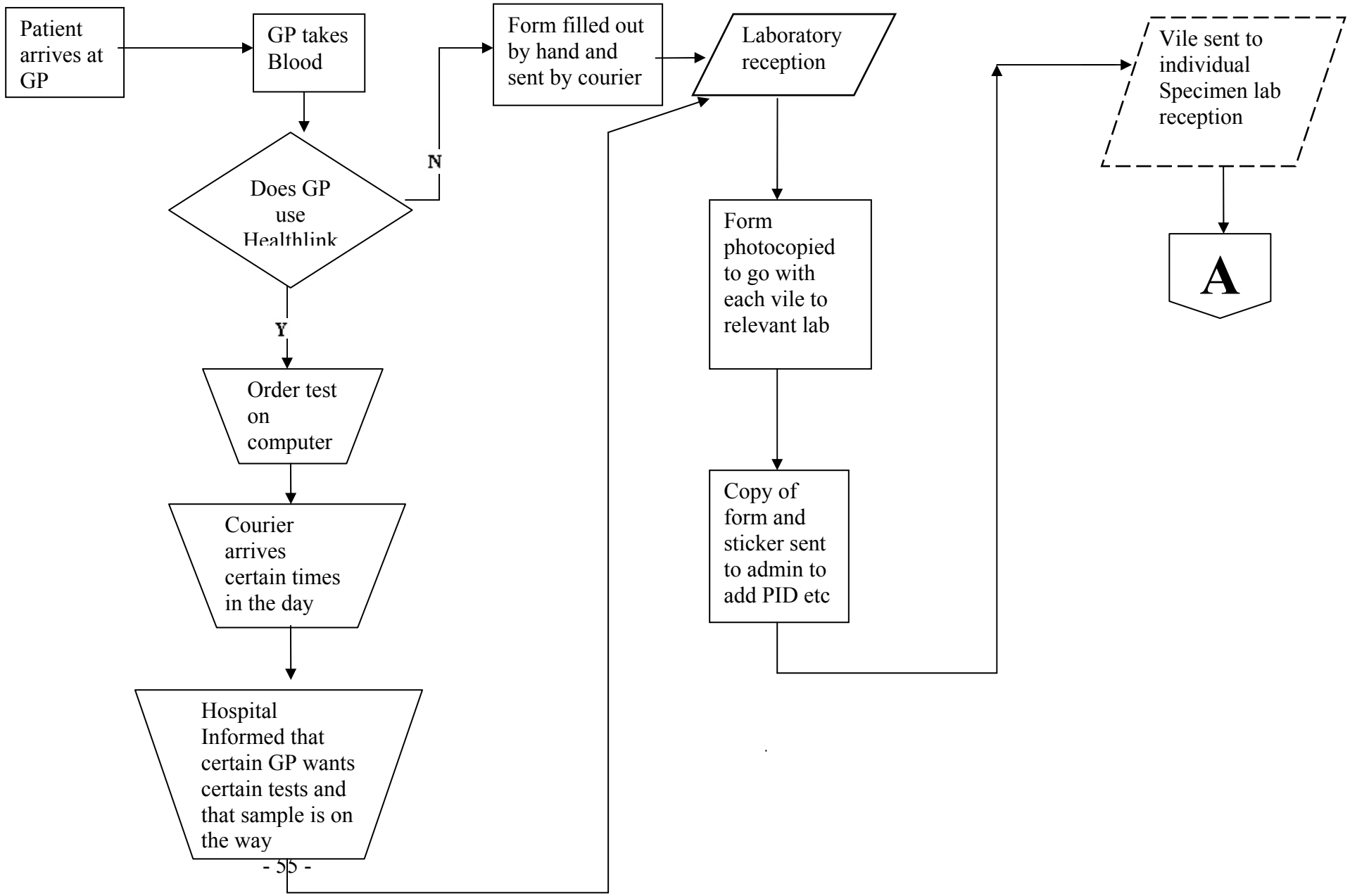


Figure 3: Data flow at specimen reception (Non hospital patient samples)

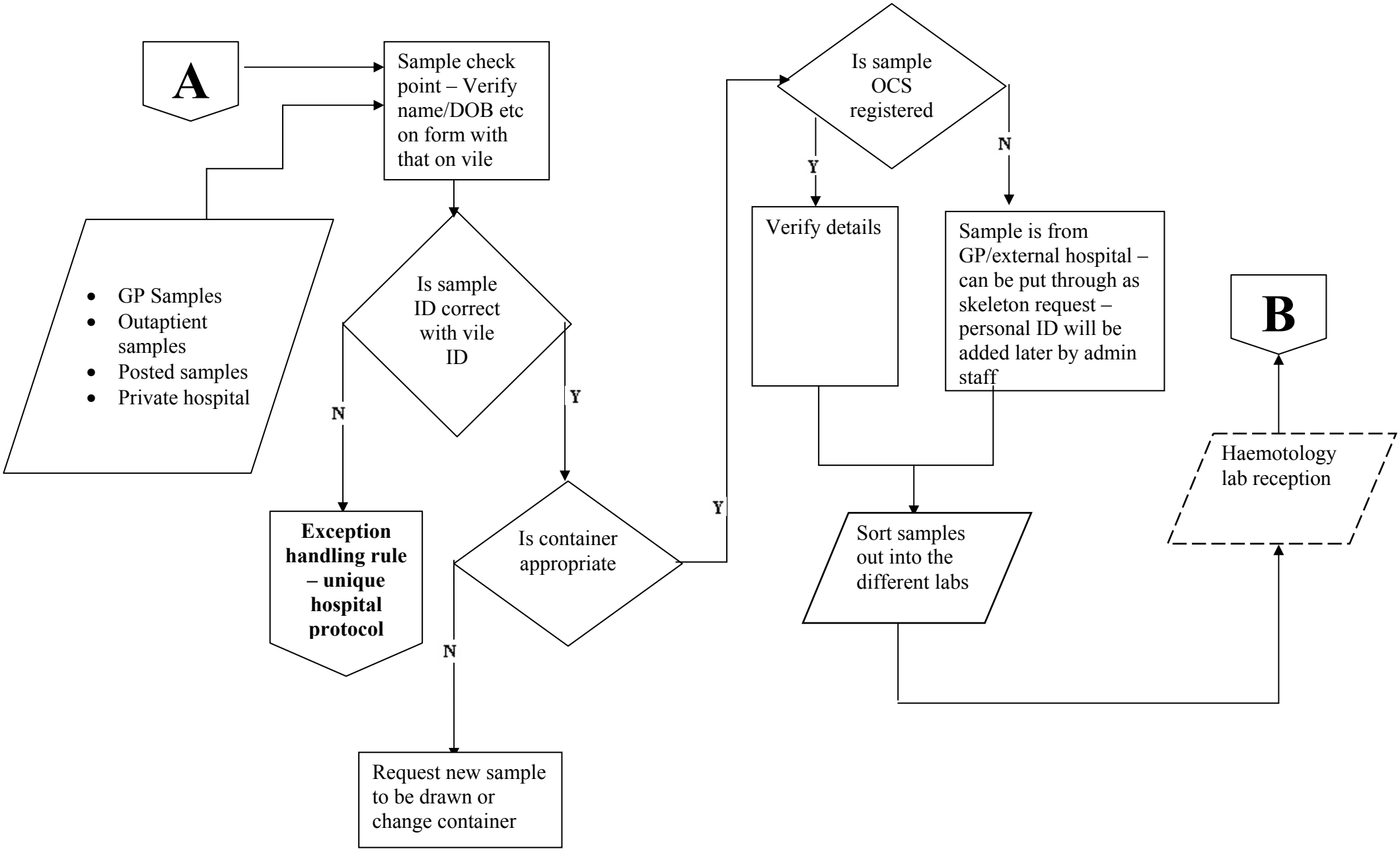


Figure 4: Samples registered for analysis in hematology lab

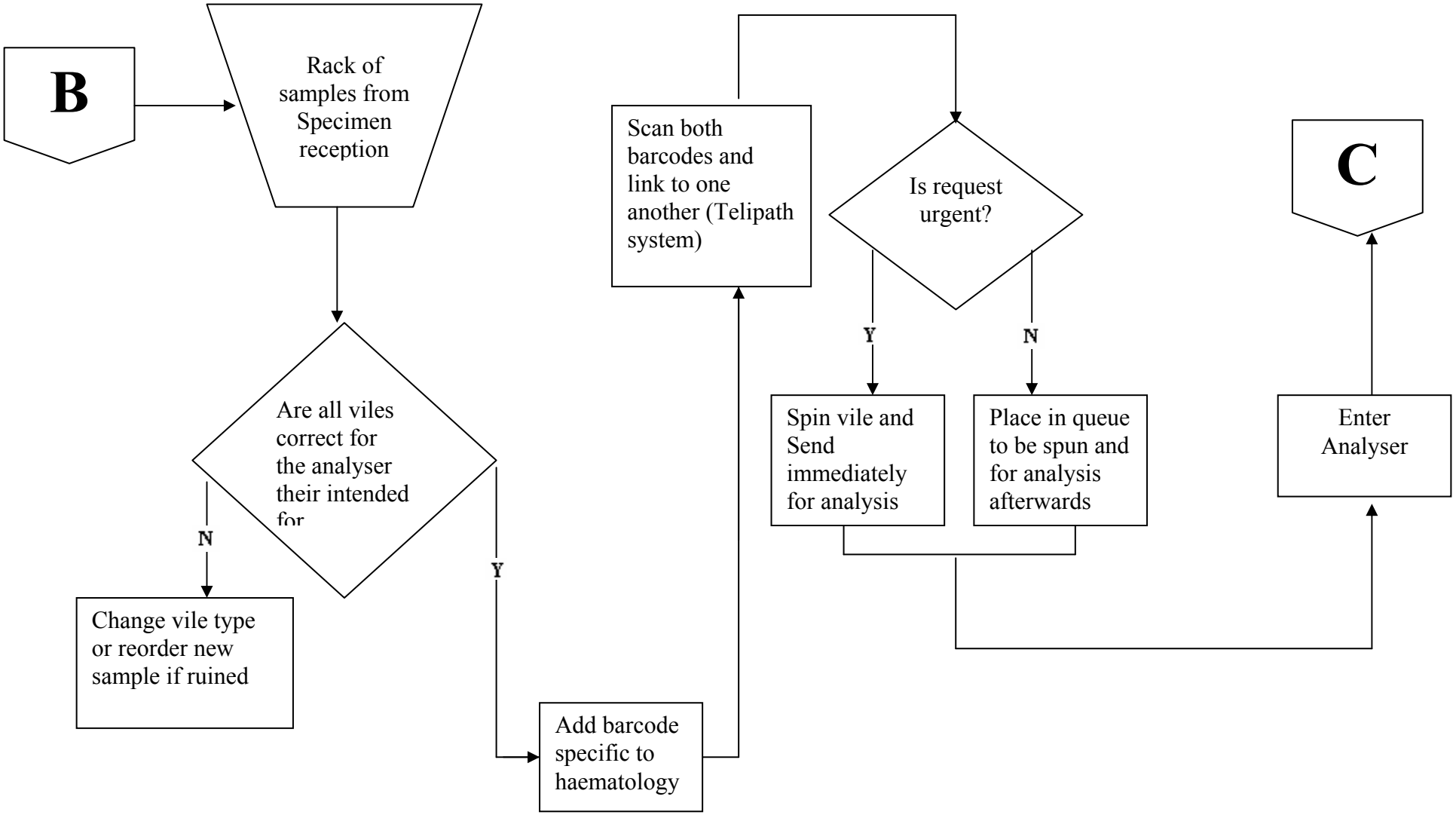
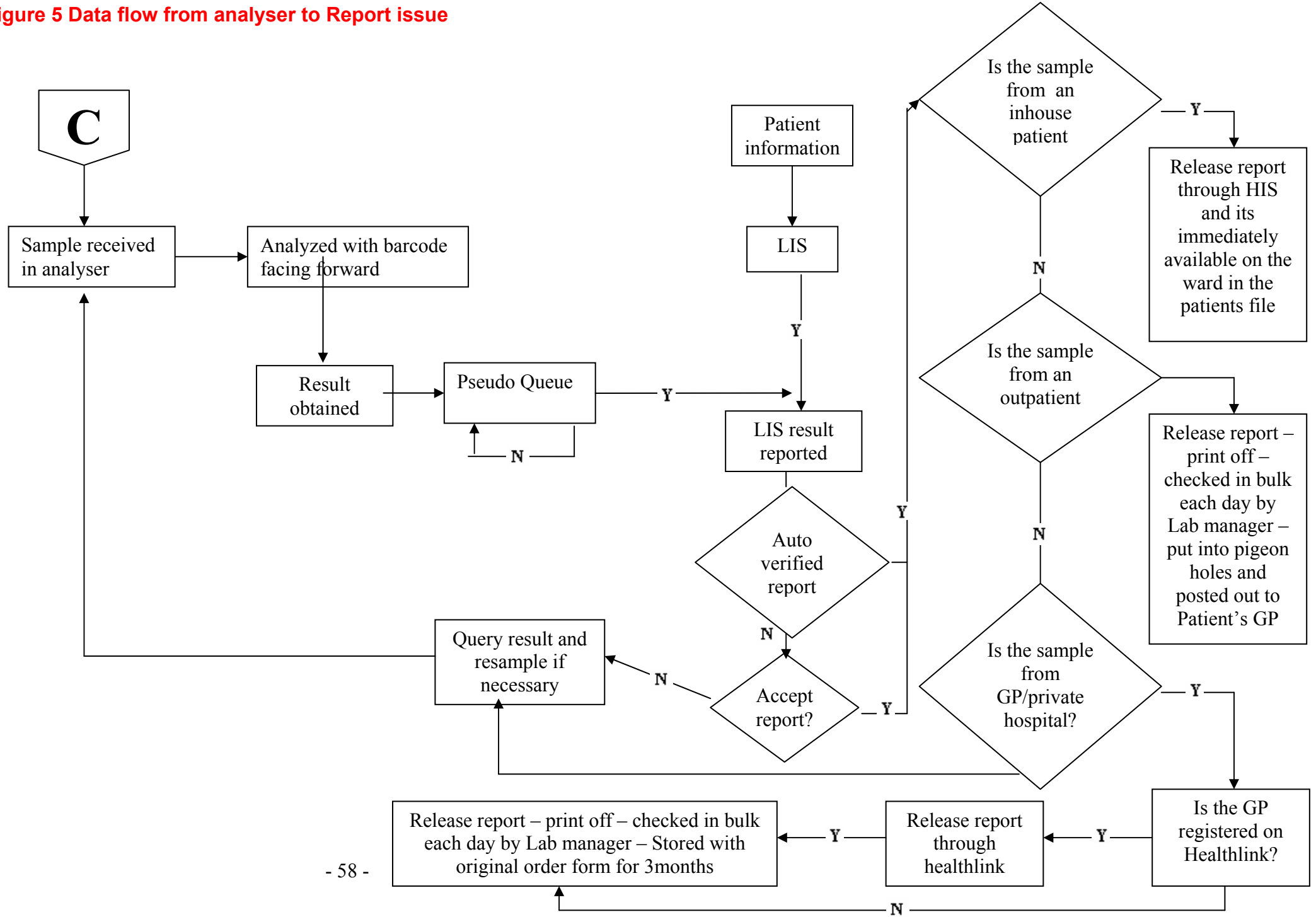


Figure 5 Data flow from analyser to Report issue



4.4 Beaumont Hospital, Dublin.

In-house patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis. In-house patient refers to any patient that is a registered patient staying in the hospital at the time of testing, i.e. blood will be taken at bed side but a phlebotomist.

This is either classed as “Urgent” or “Routine” – although it has to be noted that in the case of urgent there is actually 2 types of urgent – the type that has to be drawn from the patient immediately and sent for analysis (critical) or the case that the doctor simply writes urgent as a formality and in reality there request is simply to have the results for analysis the following day at morning rounds.

The status assigned to the request determines how it is processed. If the sample is classed as “urgent” it is dealt with in the following way:

1. Phlebotomist draws blood from patient immediately.
2. Patient is identified and the exact “episode number” is selected.

NOTE: Episode number is a unique patient number assigned to each individual every time they enter the hospital.

3. Request for specific tests is then added to the BHIS ordering system. Each test is identified by a computerised code.

Note: A note is added beside the test request to say that the request is a STAT request, or “urgent”.

4. Barcode generated and attached to each vile of blood
5. Blood sample and request form sent via vacuum system to the lab.
6. Upon arrival at central lab the vacuum container with the tubes inside is then opened by staff and sorted into buckets as per lab.
7. The vile barcode is then scanned onto the computer system to verify to the ward that the vile was delivered to the lab and is being processed.
8. Each vile is then sent separately to each section necessary for analysis, depending on tests requested.
9. The ward label is used as the lab label in this case, so there is no need to attach an independent lab label and link it to the ward label. This saves

time in the processing of the vile and also saves money in the reduction in labels printed per year.

10. All patient details are now all available on the LIS.
11. The STAT or “urgent” samples are sent for immediate analysis. The non-urgent, or routine, samples are sent into a waiting queue and analysed in order.
12. Specimen is decapped manually, which is a very time consuming process.
13. On routine samples there is a delay in terms of batch size until analysis will take place, approx 100 samples is sufficient in the queue to start processing.
14. The less tedious part of this whole process is the actual analysers. Once the blood has been spun (approx 5 mins for this) then in less than 45 mins the patient result will be available on the ward to the staff via the ordercoms system.
15. “Normal” results are automatically approved by the analysers and only “questionable” results are triggered for intervention from the lab technician for analysis.
16. No paper report is generated anymore for in-house patients, as thorough research on behalf of the lab showed that only approx 20% of all reports printed off actually made it physically into the patients file. The report is accepted by the Chief Medical Scientist and appears automatically on the HIS available for the staff to read on the ward.

Routine bloods are drawn however in a separate manner, as follows:

1. Request is generated against a patient in the BHIS system, through the ward computer.
2. Patient is identified as usual using name, episode number etc).
3. These requests all go to one central location and are printed off at various time during the day, but the bulk of which are done in the morning.
4. The computer then schedules all these phlebotomy procedures for a time during the day, allowing enough time to draw the blood and label the bottle in-between each appointment.

5. This schedule is then printed along with a series of labels for each vile and given to the phlebotomist.
6. The phlebotomist then goes to the ward with their list of patients to draw blood from. The blood is drawn at the bed side and the corresponding label attached.
7. These viles are dropped into a central location on the ward to be collected at various times during the day by the hospital porters and brought down to lab reception.

After this the same sequence of events as take place above for the STAT samples, from no: 6 onwards, occurs.

Out- patient:

The flow chart always begins with a doctor requesting blood – i.e. patient need for their blood to be drawn and sent for analysis.

These are all classed as “Routine”. There are two different type of samples that come in, outpatients, as in patients of a GP or hospital doctor that are sent to the hospital outpatient clinic to get blood drawn, and there are bloods sent in directly in viles that have already been drawn by a GP. The flow of the blood from the GP is as follows:

1. Blood taken from patient by GP.
2. There are two ways of ordering blood tests for a GP:
   - If the GP uses the software package called HealthLink, as discussed earlier, the request is put into the system and a copy of the request printed by the GP and put into the bag with the blood.
   - If not then a written request form is filled out and physically sent with the vile in the bag to the hospital.
3. The courier is sent around to all the GP surgeries that have requested blood sampling and delivered everyday to the hospital between 11-2.
4. The racks arrive at the sample reception.
5. The bag is opened by admin staff who removes the viles from the bag and place on the counter with the relevant form.

6. The patient's details and tests requested are then entered manually onto the system, taking approx 3mins per patient without distractions.
7. BHIS label is printed and attached to each vile.
8. The bloods are then separated into each specific area to be transferred to the necessary labs, i.e. biochemistry lab is separate to microbiology lab etc.
9. The form with the sample is placed into numerical order for the day and stored for up to 6 months at a time.
10. The vile arrives in the lab and is scanned once more to ensure the patient details and test requests correspond with those on the computer.
11. The samples are then sent into a waiting queue and analysed in order, i.e. first come first served. As the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. >2hrs old. This takes approx 5mins per vile.
12. Once spun, the specimen is decapped manually, which is a very time consuming process.
13. On routine samples there is a delay in terms of batch size until analysis will take place, approx 100 samples is sufficient in the queue to start processing.
14. The analyser itself is the least time consuming part of the whole process.
15. "Normal" results are automatically approved by the analysers and only "questionable" results are triggered for intervention from the lab technician for analysis.
16. All accepted reports are then sent from the analyser to the LIS.
17. A paper report is generated and they are printed with all GP requests every morning in bulk. These are then signed by the Lab manager, divided alphabetically into pigeon holes, and sent back to the GP/Doctor (once reviewed and signed off at the lab) who requested the test.
18. If the GP does use HealthLink then an electronic report is generated and sent back to the GP (once reviewed and signed off at the lab) through the HealthLink software immediately. A paper report is also generated at this stage and sent out.

19. The patient request form from the GP is stored for 6months and then discarded.

The flow of the blood from the outpatient's clinic is as follows:

1. The in-house outpatient blood samples are done in a similar fashion, except the person is physically in the hospital.
2. The receptionist takes the patients details as they arrive at the phlebotomy clinic and enters their details onto the BHIS. They then wait in turn to be called into the room for the procedure to take place.
3. A barcode is generated on a form and printed inside at the nurse's station where the blood will be drawn.
4. The patient is then called and asked to verify their details, name date of birth and address.
5. Blood is drawn and then put into the bin for the test requested, e.g. the specific lab it is to go to.
6. Blood is sent up to the lab by courier at regular intervals during the day.
7. At each individual lab reception the vile is then rescanned to verify patient details.
8. The samples are then sent, like all other samples, into a waiting queue and analysed in order, i.e. first come first served. As many of the samples have been waiting around for testing they need to be spun for longer than fresh samples – i.e. they are >2hrs old.
9. The analyser itself is the least time consuming part of the whole process.
10. "Normal" results are automatically approved by the analysers and only "questionable" results are triggered for intervention from the lab technician for analysis.
11. All accepted reports are then sent from the analyser to the LIS.
12. A paper report is generated and they are printed with all GP requests every morning in bulk. These are then signed by the Lab manager, divided alphabetically into pigeon holes, and sent back to the GP/Doctor (once reviewed and signed off at the lab) who requested the test.

Figure 1: Data flow chart for In house patients required to give blood for analysis.

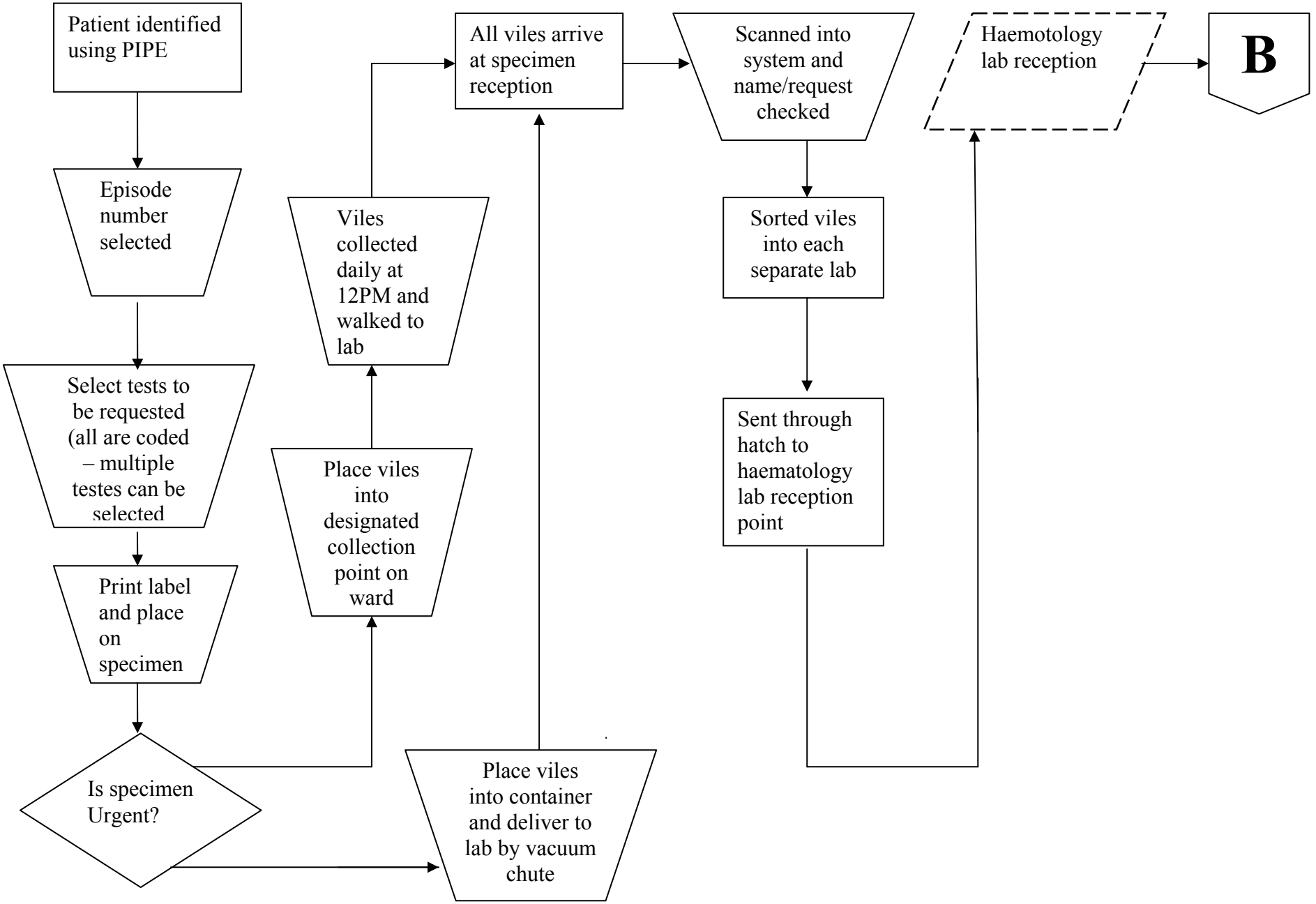


Figure 2a: Data flow for Outpatients required to give blood in hospital

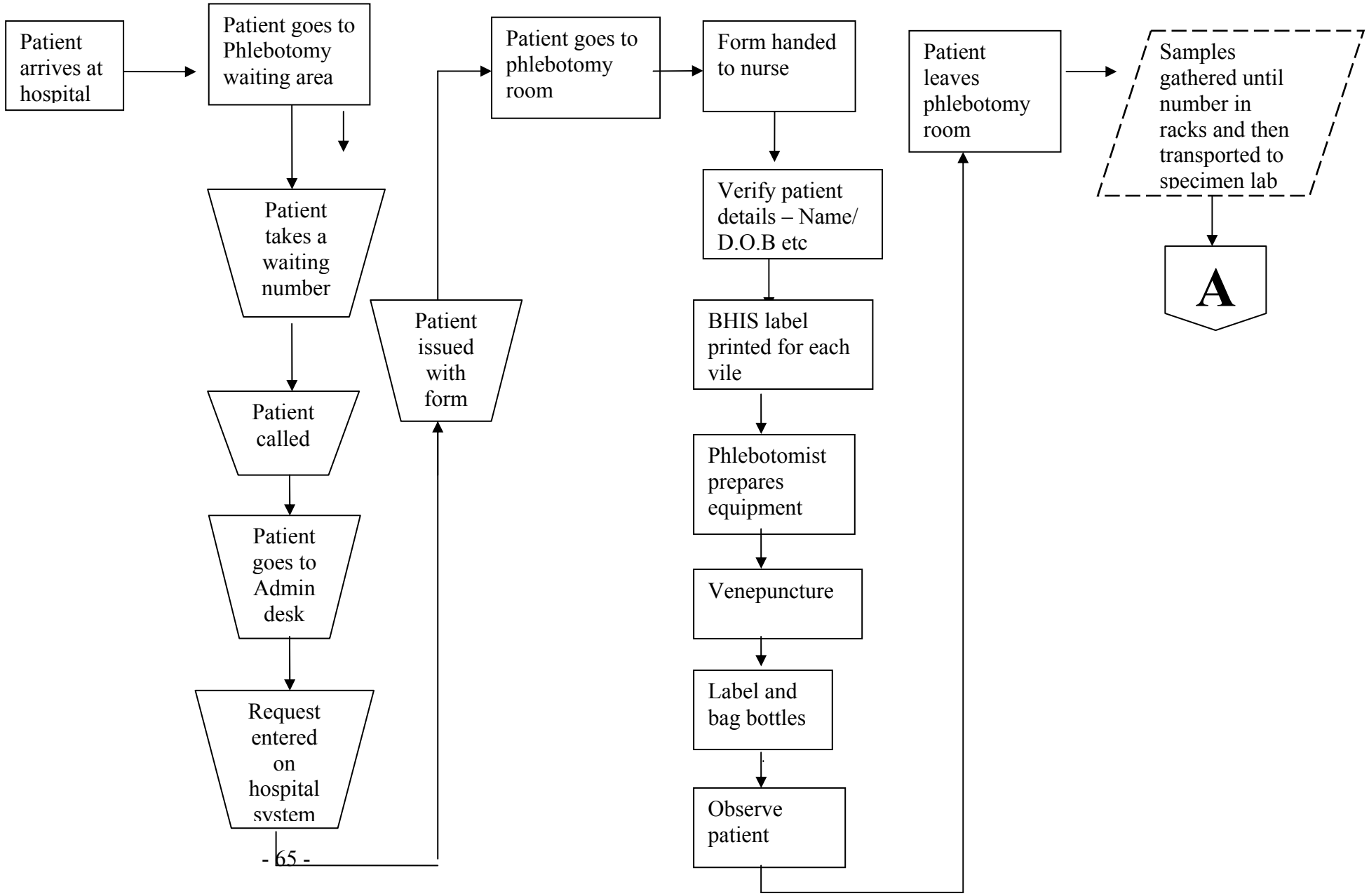


Figure 2b: Data flow for GP's blood samples analysed in hospital

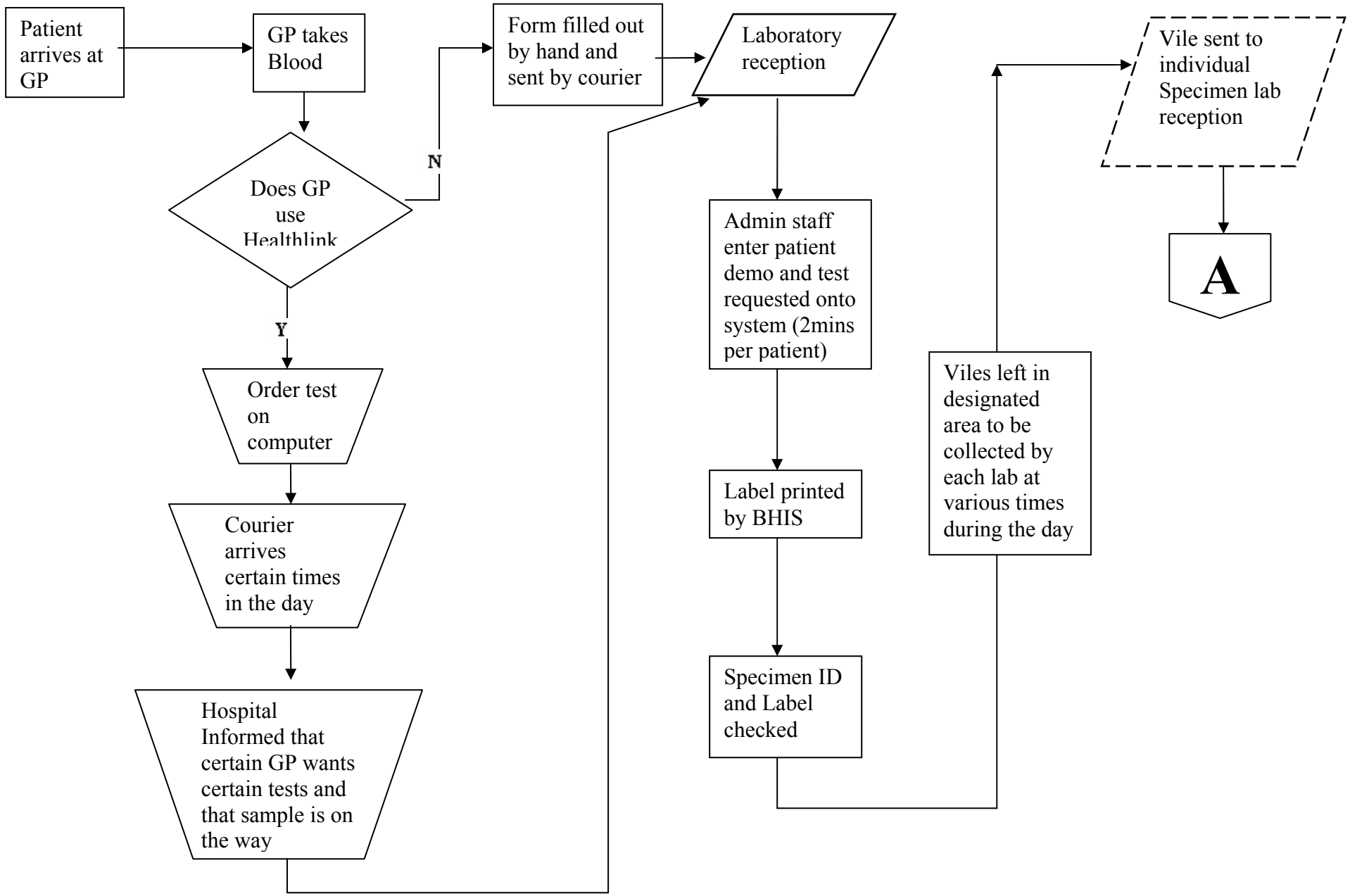


Figure 3: Data flow at specimen reception (Non hospital patient samples)

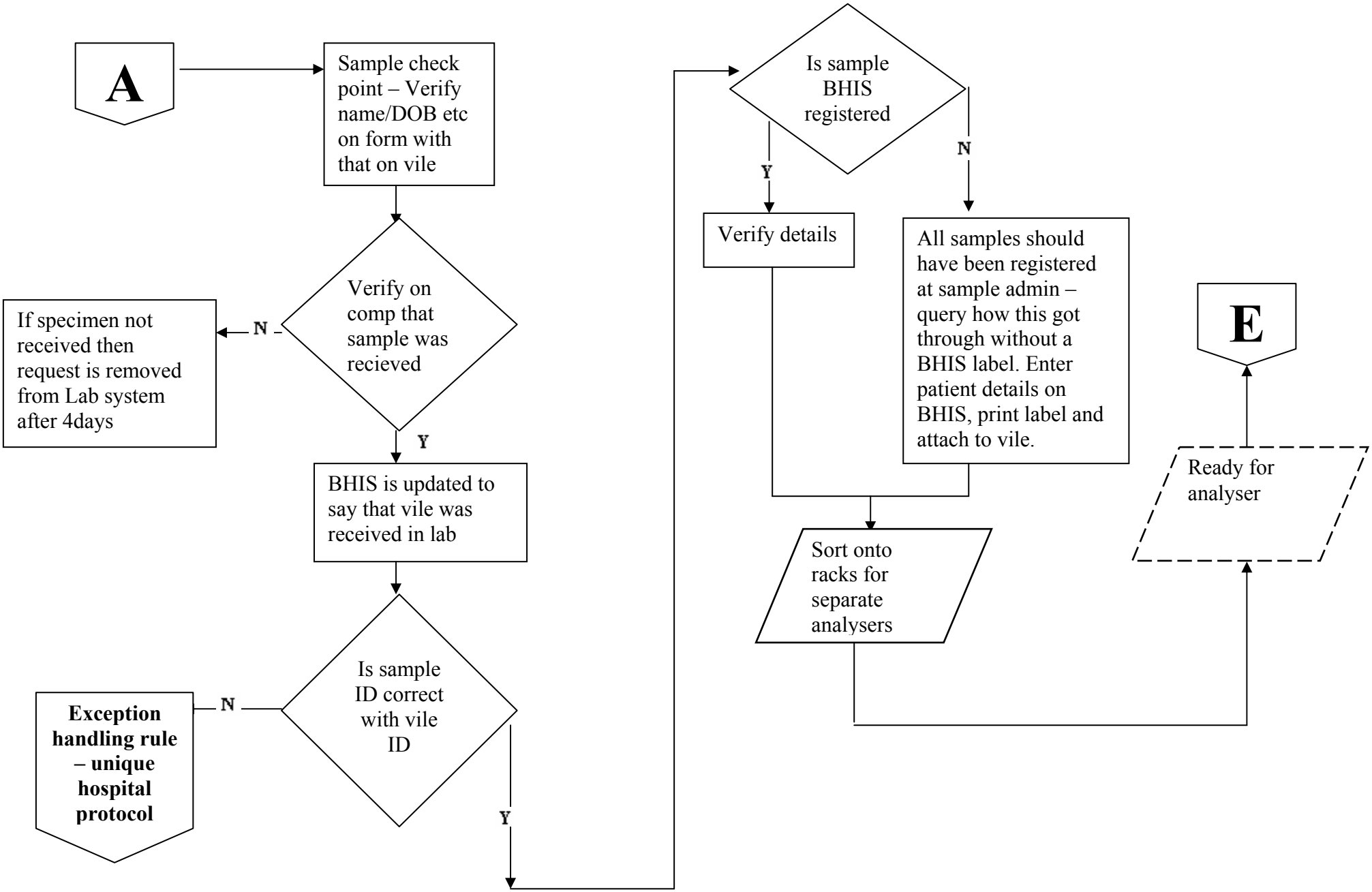


Figure 4: Samples registered for analysis in hematology lab

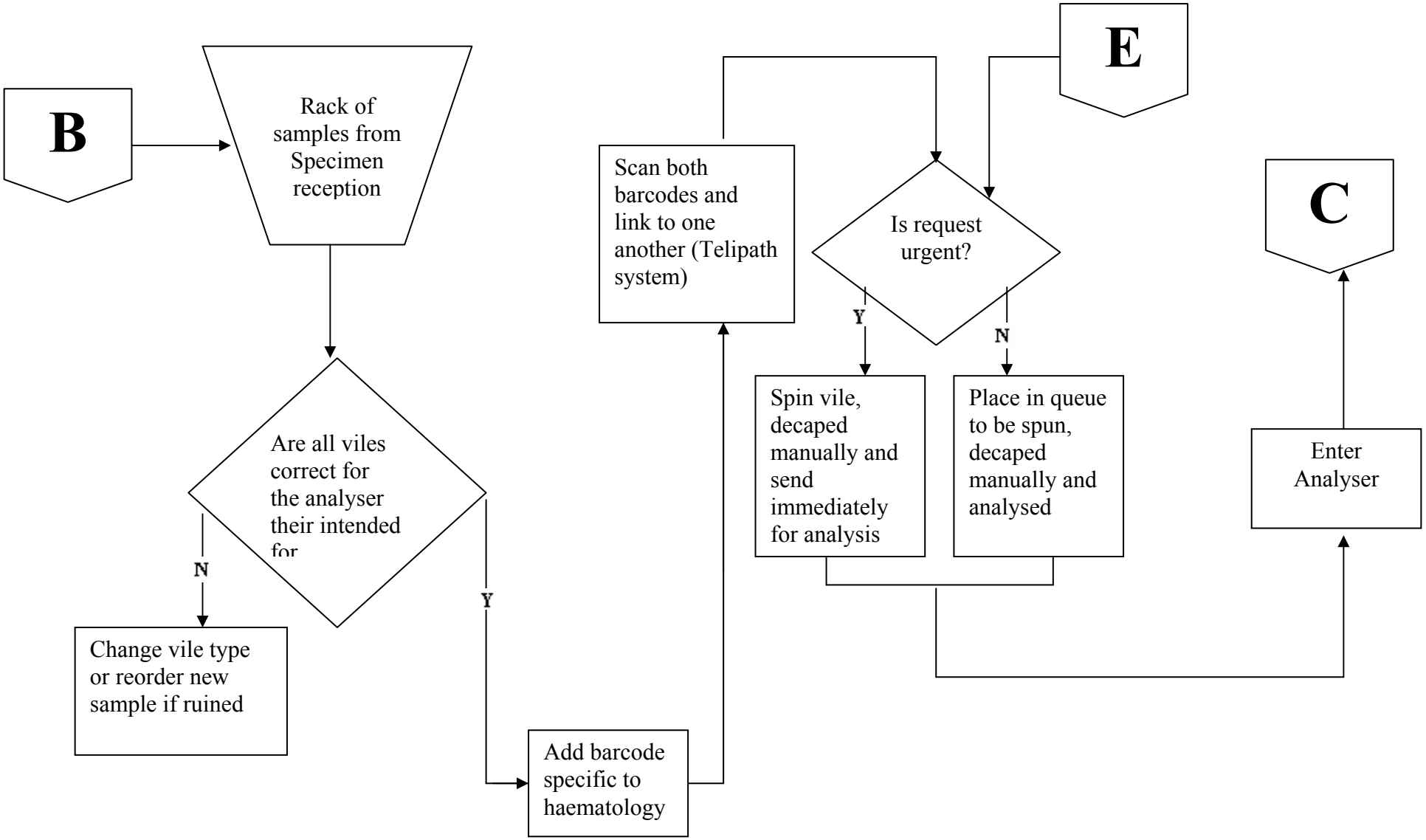
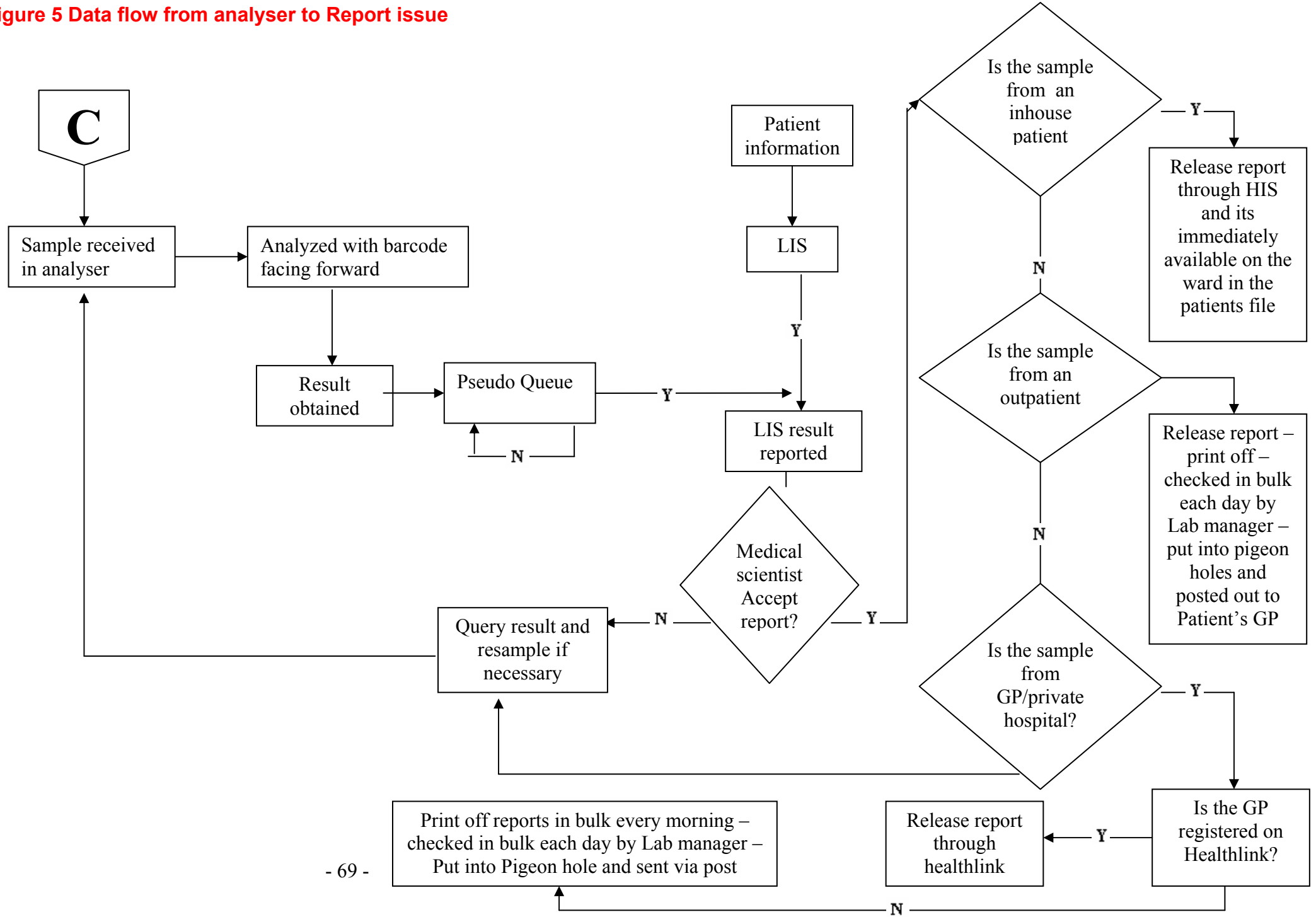


Figure 5 Data flow from analyser to Report issue



Chapter 5 Discussion:

Information technology has done much to take healthcare from the basics of patient registration, billing and clinical order processing to helping professionals effectively direct patient demographics and managed care across diverse settings, as well as direct the entire care continuum via the electronic patient record.

While these advancements have helped tremendously with data management, vast opportunities remain to leverage information technology's power to improve productivity, streamline processes and tailor systems to users' specific needs. However with the increased focus in recent years on potential savings in the healthcare industry, these opportunities wont be long coming about.

Some Facts and Figures:
In 2006 St.James's hospital processed 761,000 biochemistry results alone, a 23% growth on 2005. This figure alone illustrates the sheer volume of growth seen from year to year within the hospital laboratory. The only way to counteract the increased volume, without having to severely increase the workload, is to create a more efficient working environment, and hence reap the benefits directly of this boost.

Labs and hospitals are dynamic organizations that suffer directly when constrained to static environments. Change should be considered part of a natural and vital evolutionary process. The approach to information management technology must be predicted on an ability to deal comfortably with change whenever necessary.

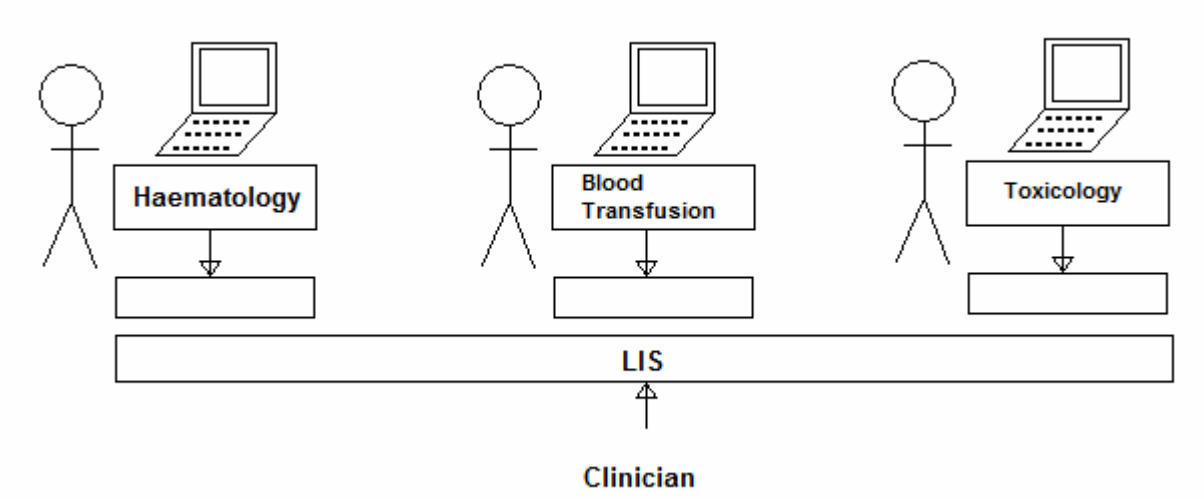
The issue of healthcare is always topical when I.T. is mentioned. A report issued by the HSE recently recommended the widespread rationalisation of lab medicine services. The main aim of this is to offer more efficient and guaranteed “turnaround times” for tests ordered by hospital doctors and GP’s.

The health service to date pays a €328 million annual bill for clinical pathology laboratory services.

Information is the foundation of any patient flow initiative. In analysing patient flow it was essential to establish what exactly a general lab looks like. In analysing data flow the capture, integration and sharing of information, both within and across departments must be considered. While it sounds simplistic, this critical foundation can be immensely challenging to hospitals with numerous information systems and departments that operate as silos.

Most information capture should happen by integrating existing systems and technologies. These systems enable more intuitive data collection because they are already used by providers and staff. Examples include the telephone, pagers, PDAs, HIS, ADT and scheduling systems.

From this study the lab at the moment in general can be described as a room with multiple separate analysers and computers that upload information onto a common network, the laboratory information system. This subsequently uploads the info onto the hospital information system. These computers are independent in the way that they work independent of each other, and also from each individual station the clinician cannot access data from any of the



other stations.
It can be generalised as bring like this:

From the diagram above:
Each workstation works independently and uses individual software to connect into the LIS. The data from this computer cannot be viewed by any of the other workstations across the LIS.

In this research it was found that in each of the hospitals the information system they utilise actually segregates each lab and at each individual lab work station you can only access the results for that particular lab, i.e. if you are in the biochemistry lab you will only have access to the results for that patient from that particular lab, and you cannot access results for the same patient for virocology or toxicology.

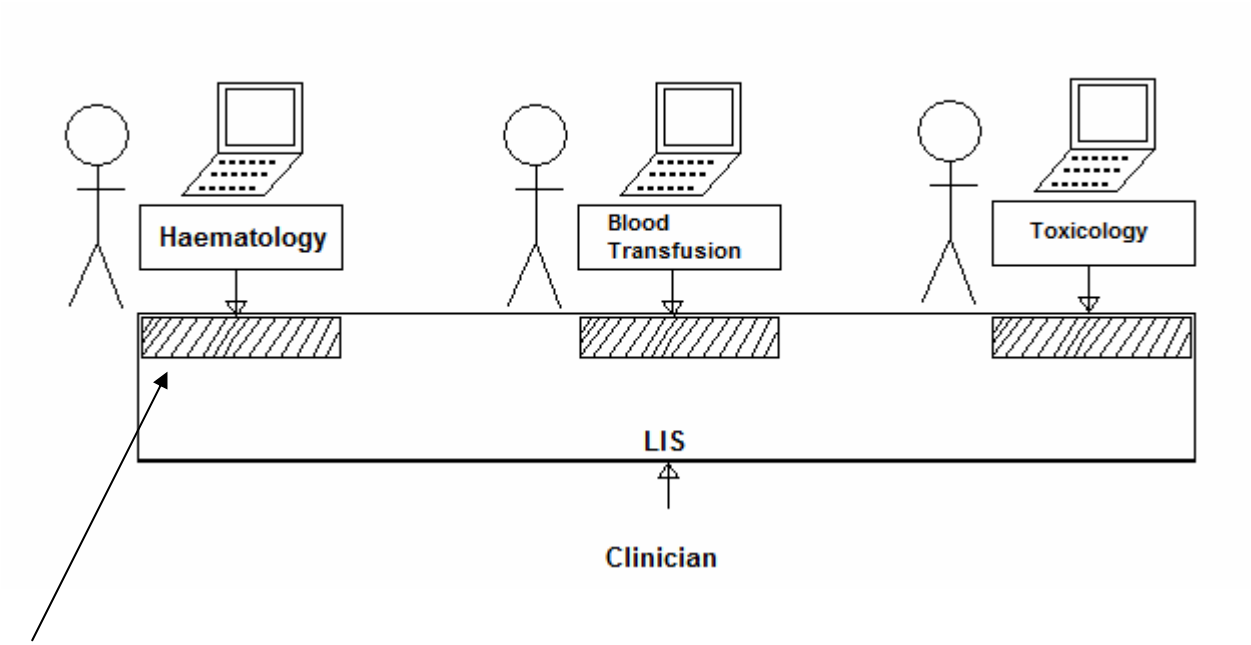
This issue becomes a factor in the efficiency of the lab when the lab medical scientist is reviewing the lab results to release them, i.e. if the lab manager has a query on the result, say a leukaemia patient who has bloods taken every day and suddenly has an extremely high/low blood count. In this case the lab manager has to physically go to the blood transfusion lab and see if the patient had a blood transfusion the previous day which would account for the improved blood count, or ring the ward to check if the patient had a dose of chemotherapy the previous day which would account for the low blood counts. In a hospital where the majority of patients getting bloods taken every day are extremely sick, this takes over a lot of the time of the lab scientist.

If all the lab systems had a common database then the whole processing of verifying the result would be much smoother and more efficient. If the LIS and HIS could talk to each other then when a note is made on the HIS about a patient then it automatically updates on the LIS and there is no need for the lab scientist to move to multiple labs to find a result in order to verify the lab result.

A further draw back of using independent systems in the lab is that if the GP sends in a sample with the request for multiple tests to be carried out, then the admin staff at the lab sorting place have to photocopy the request form and place a copy with each vile and send it individually to the lab. This is

further delaying the already extended GP request turnaround time. If the lab central area could link the requests to each vile for each lab in one central place then this would remove the need to photocopy each GP request form and would speed up the whole process.

What the lab needs is a fully integrated system; one that talks to all stations and allows the exchange of relevant data across. This would mean that each lab could input data to do with that lab directly, but also other labs could see the data and use as they wish, without being able to change any details at any time.



This part here relates to some form of complicated software that converts all the information from a specific piece of equipment/analyser into a common form that could be viewed by any other equipment/analyser on one single LIS. It would be a form of software that enables single point of access to multiple ranges of data from multiple different analysers. This would allow lab personnel access to results from various different labs from a single workstation.

In an interview with lab managers that utilize middleware software, as explained in detail in chapter 3, the main efficiency gains were as follows:

- No need to manually verify “normal” results. An advanced algorithm embedded in the software, and developed as a result of extensive research, is used to identify results from the analyser considered “normal” and auto verify these, freeing up the queue and also the workload for the lab clinician.

- Rules can also be set up for various groups of patients, for instance patients that arrive in every Tuesday for samples to be drawn with the same analysis due every week then these can be scheduled into the system. When the patient is scanned in then automatically the system will print a label with all the testing to be carried out on it and these further speeds up the process.

- The clinician can also set up certain parameters to look at on certain groups of patients, e.g. chemo patients must always have their WBC looked at, and kidney patients must always have their RBC and Hgb looked at. This data can then be further used as an audit tool, to establish the values for certain parameters of patients in the hospital.

- There is a further benefit of this programme whereby additional data can be flagged on the screen and a note added. There is a space on the screen where comments/observations can be added for a particular patient. This will then remain on the patients file and will be viewable on the next incident. For example if a renal patient has very low Hgb then a comment can be added requesting the doctor to check urine as there is some concern over the blood result. The next time the patient gets blood taken the clinician will also be more alert to checking for small discrepancies in this blood composition and aid in the diagnosis process.

Further observations as a result of this research were that very little QC is done within the lab itself, outside the QC carried out on the instruments individually. With the addition of further software into the lab, report can be generated on many different parameters, such as audit the trail per result, per

patient, per type, e.g. outpatient, in-house, GP etc. Also parameters such as volume of results auto verified etc can also be reported.
A further QC parameter that could be analysed is to aggregate a severity of system ranges, i.e. accumulate many different parameters that are drifting out of a specific range, and alert the user if over time this value is increasing. This is a clear indication of the condition the system is in from one day to another, and also can be an early indication of potential system failure, which can be rectified through calibration etc, with minimal disruption to throughput.

Results could also be analysed on a per system basis, or by a per lab basis, or by efficiency measures for the lab as a whole. This can be done on a daily and weekly basis, and may be a clearer indication of future peaks/dulls in throughput.

Furthermore all QC data can be electronically exported to an excel/access database for further analysis and also for storage. This allows easier to access to historical data and easier comparison of data from month to month, year to year etc.

In terms of auditing the processes that are carried out in a lab itself, there are also external independent auditors that will review the lab at certain times during the year and issue a report and recommendations. Multiple QC checks are done everyday on the analysers, with the main bulk being done prior to and post testing everyday.

A further QC check that is carried out by St.James's hospital is that they use an external auditor called NAQUAS or NUKQAS. This organisation has a large client database from multiple labs in many different regions. The org. requests the lab to run a certain set of controls and send all the data, i.e. the analyser reports back into them for review. The data is then analysed 15 different ways by statisticians in terms of accuracy of the result, calibration of the system, power of the analyser itself (e.g. to what level can the analysis be carried out) etc. Similar analysis is carried out on the information from the other labs and a report issued. The report makes comparison with your

specific lab to all the other labs in terms of the 15 parameters, and also releases figures in terms of where on the scale is you lab. Since St.James's hosp began using this audit type they have been continuously stationed in the top 95% of all labs analysed. This report is a good indication in the confidence one would have in the result they have been given from that lab, and inevitably how reliable the diagnosis that follows is.

These reports could reveal information to the lab manager that allows for changes to be implemented, and hence improve the efficiency's in the lab, directly impacting turnaround time per sample. If this was an ongoing audit parameter that was reported on a regular basis then this would inevitably leads to improvements with the lab itself, and possibly the hospital.

The main issue in terms of delaying throughput is in the entering of data onto the system. Computer programmes can accommodate this function, and simply scan all data from the request form into the system and use this way. The results for one particular lab can be reviewed independently or in conjunction with other data.

One of the most time consuming parts of the whole lab process is in the registering of the details of bloods received from GP's. In Ireland the attitude to computerised programmes to aid the lab in this process, has been quite negative. The way the HSE runs the GP requests in this country could be adversely influencing this. In England for example, the GP's pay directly for each blood sample analysed, so the less efficient the manner at which the blood/details gets to the hosp, the more money it costs the GP themselves. So it is basically in their best interests to work with the lab manager and evolve the process. The hospital also gets a certain amount of money for each sample run, so it is in their best interest to get the money with as little costs involved as possible. The lab manager is therefore further encouraged to increase efficiencies and generate more profit, as it is a means of directly generating revenue for the hospital.

However the system in Ireland is somewhat different. The sampling of bloods by the hospital is carried out as a free service to GP's. As this process does not directly cost the GP any money then they are less likely to invest time/money back into it to help in the improvement of such services.

This issue becomes more apparent when scrutinizing the success of the HealthLink project in Ireland, or in this case the lack of success. As mentioned in chapter 3 HealthLink was a project set up in 1995. In St.James's' hospital alone only approx 16.5%, approx 100 out of 600, of all GP's that use their services actually utilise the HealthLink programme, while in Beaumont only approx 15 public and 40 private clients utilise the service.

These figures are extremely low considering that in 1995 the Irish government offered free personal computers (PC's) to try and encourage the less than enthusiastic GP's to try out the programme. This offer does not seem to have had the desired effect on the population of GP's currently in Ireland.

The main drawbacks from the project, as found in discussions with the four lab managers, are:

- The GP's surgery and the hospital lab cannot always both accommodate 2-way-ordering system. So even if the end result is sent over to the GP via HealthLink, hence cutting out the need to post every repost, there is still the drawback of severe admin charges remaining at the hospital once the blood arrives.
- The confidence in the computerised system is quite low. This is an issue with many new computer programmes that are introduced, and when it's a patient's health at risk the consequences are even higher. Even though GP's are beginning to use the system, the Lab manager in St.James's' says that multiple users still ring up and double check results, or request the original report sent out to them via post aswel as over the net. These tasks far outweigh the benefits of introducing this type of system in the first place. As there is so much at stake, GP's have to check and check again with all results, and until a huge

confidence grows in the software which is depicted back to the GP's, the issue wont change in the future.

- Although there is poor uptake from the GP's there is also a slight hesitance surrounding the project by some lab managers. If, for some unknown reason, a result is released and discovered some time later that there was a mistake in it. This does not happen very often but it is not unheard of. The lab manager would in the current process either ring the GP with the issue or if caught in time, simply prevent the physical report from going out in the first place. HealthLink allows the ability for the lab manager to alter a result after is has been submitted. However if the GP has already downloaded this result and does not update this result again then the initial result will stand. The lab manager usually ends up phoning the GP personally to discuss the case, and sending out the amended report by post. This could cause confusion of the original report was printed off by the GP, and then 3 days a later a further report for the same patient arrives with different results showing on it.

The issue of the ever increasing cost to the lab, and hence the hospital, each year to employ clerical staff is currently being addressed by St.James's hospital. For the typical hospital with multiple information systems, integration is always a challenge. It was outlined at the beginning of the project that an overhaul of the entire lab was not an option due to the sheer expense attached, although alternatives to enhance the current process would be taken into careful consideration.

In terms of data flow within the lab, the main areas highlighted as causing severe ineffectiveness in the lab is that GP's samples are processed altogether and delivered to the hospital between 9am and 5pm, with little work carried out outside this time frame, and if so, at a severely increased cost. A further concern was at the lack of consistency in the labs in Ireland today, with the general condition of the laboratory estate around the country as "poor" and "outmoded".

One of the obvious places where efficiency is compromised is the sheer volume of repetitive actions carried out in the lab. In all 4 of the labs the bloods are checked and labels added when the blood is drawn. This is then sent by chute to the central lab sorting office where it is checked and sorted into each individual lab. These are then sent into the individual lab, either through a hatch as the lab is in close location or brought in by person. Then once received into the lab these are sorted once again and checked for patient details etc.

The introduction of a patient flow-specific solution should enhance, rather than attempt to replace, current systems. Ideally, it will enhance current information sources through rules-based workflow. Rules-based workflow makes information actionable, moving information from the static realm into the dynamic realm of workflow automation.

Thorough research was carried out by St.James's hospital into the many different possibilities in obtaining a more efficient method of GP administration. It was decided that the easiest way to get the information from a written method to an electronic method without the use of clerical staff was to scan each document using a computerised scanner.

The main benefits of this are that the time taken to enter the patient's details is severely reduced, meaning a linked reduction in the number/price of clerical resources. This also has the benefit of electronically storing all data, so there is no longer a need, like the current situation, to store the paper version for an extended period. Electronic copies of forms can be stored indefinitely and retrieved at any time at the tap of a button. There is the additional benefit of providing both the lab manager and the GP with a clear audit train for each sample, from the time it enters the hospital until the report is released and issued. At the moment the patients details are entered onto the system in bulk, so it could be some time after the sample is received that the details are entered, not providing the lab manager with a clean audit trail.

The first option was simply to scan in each GP's request form and link via a bar code to the vile in question. However initial feasibility investigation brought an important issue to light – the clarity of GP's writing was quite poor. This is an issue for the current clerical staff already, but when the form is scanned in the clarity is compromised even further. At the moment if there is a question on any of the forms the clerical staff simply ring the GP in question and verify this before entering onto the system. If the forms were scanned in and after say a month an issue arose and the lab manager pulled up the form to question it, if it was illegible then it is of no use whatsoever to anyone.

A second attempt was to use character recognition software on the forms to electronically upload all the details into electronic format. But a similar to previous was discovered. The complexity needed in the software to be able to distinguish between letters on the GP's handwriting was so expensive it would far outlay the benefits.

The third attempt, and the one they settled on, was to use a custom made form for each GP, that they could print off from their computer. This would have their name address etc already on it each time, so reducing the repetitiveness at their end also, and would have a list of possible test requests that are simply ticked if applicable. Therefore all forms that arrive in are of the same format, easily recognisable by the computer software, and there is no question over possible writing discrepancies due to the fact that the whole form is typed. If the GP for some reason does not have a computer then they can order the forms with the GP name address etc already on it, and simply tick the boxes of the tests requested as they need them.

The foreseeable benefits of such a programme are:

- Faster, more efficient work flow
- Less repetitive work on the same item
- Cleaner audit trail from specimen entry to report issue
- Results can be categorised by GP and sent out in bulk
- Easier retrieval of historic data once database gets up and running

The main observations in this study are that none of the delays in analysing the blood samples themselves is in the physical analysis. The preparation and release of the results are the most time consuming and least efficient part. Each sample actually only takes approx 5mins to analyse, but approx 10mins taking into account that there is QC etc to be carried out prior to testing each morning and evening. The main delay is in the labelling and counterchecking of samples to ensure there is not chance of a mix-up with the results.

There are however some fundamental issues that are causing delays. In the outpatients clinic the bloods aren't collected and sent to specimen sample area until a certain batch has built up. If there are only afew patients scheduled into the clinic over the course of the morning, the clinic opening hours are approx 9-11 each day, then the lab will not have to do any outpatients bloods till the bulk arrive at 1. Similarly if multiple patients are scheduled in for testing in the same day , then the lab will deliver multiple viles at once and there will be a sever increase in workload at these times, and then a trough when awaiting the next bulk batch.

The bloods from the GP's arrive in a similar way, except for in St.James's hospital that is. In St.James's hospital each GP request is entered onto the lab system and issued with a label. One label is put onto the vile and one attached to the GP form. The vile is then sent as a "skeleton" request to the lab for analysis, while the GP form goes to the admin area. As the lab is physically analysing the blood sample, the admin staff are entering in the patient details and linking this to the vile by electronically scanning in a duplicate of the lab barcode. This means that in theory the admin staff and physical analysis of the blood can happen simultaneously. In fact his is not always the case however as the lab analysis takes less time usually then the admin staff would need to get through the physical entering of all patient details into the system.

In other hospitals the vile of blood stays with the request form until all the patient details are entered onto the system. This causes a delay in the time

from when the vile enters the hospital to the time it is actually analysed. The vile is then put into a box for the specific lab it has to go to for analysis. This can cause further peaks in analyser use as there is no way of the lab knowing when there are an abandonment of samples waiting to be taken. However if the sample bins gets too full the admin staff will take time out of their own work schedule to phone the lab to remove the viles.

A further delay for GP's in getting their results is that in some of the hospitals the reports were physically printed out and sent out in bulk. That mean if your request was processed on day one, the report would be released on day one, then waits in the LIS until the next morning when all the GP reports are printed in bulk, checked by the lab manager, and then further divided into the pigeon hole for that particular GP and then sent out by post that day. This will arrive to the GP in 2-4 working days approximately. Therefore the GP turnaround can be anything from 5-7 days depending on when its sent in.

The vacuum system is a further means of delay. It is the means that the majority of hospitals use to move bloods from the ward to the lab. The outpatient's clinic is usually situated close to the lab itself, and as they will have a large volume of bloods to transport each day, it is usually transferred by hand when a certain quantity is reached. The vacuum system however is a one way system; hence if someone is using the system then your sample must join a queue and will not be moved until the previous samples are at their destination. This can cause some delays in getting bloods to the lab, especially as most ward bloods are drawn in the morning so the majority of drops to the lab will be accumulating at the same time. Many hospitals have to call porters to physically carry down the bloods to speed up the process, defeating the purpose of installing the vacuum system in the first place.

Once the viles arrive in the lab reception, they are sorted out by the staff into the different labs they have to go to. The entire lab itself can span a wide area physically. The bloods have to be either collected by a member of the labs team, or brought to each individual lab by the sorting staff, at various intervals during the day. At each time there is a bulk of samples arriving into the lab at

each time, hence the lab may go from a lull in workload to an immediate peak. The sorting office only ring the lab to come pick up the racks of samples when they are at an increased quantity, and before this point it is up to the lab personnel themselves to check up on deliveries at their discretion. This is a time consuming, and energy consuming, part of the analysing process.

This is an issue when a certain sample needs multiple tests, not available in the same lab using one sample, the solution is either to split the sample up into different viles and print out multiple labels for each vile, or else move the vile to the separate lab after a sample has been taken, or else request further bloods to be taken by the phlebotomist which means further inconveniencing the patient.

A further issue is found when a request is phoned in after the vile has arrived in the lab. These tests are treated as add on's. This situation arises if the vile is already in the lab and then the doc realises he forgot to put a certain request onto it, and then he rings the lab and requests an additional test to be added to the list. If the barcode is already on the label when this additional test is requested then a further label is needed to be added to accommodate this new request. If this happens more than once then this can get much crowed and the quality of the label on the vile, for the barcode reader, is compromised. This can cause problems when the vile is sent into the analyser and may result in the analyser not accepting the sample, and a re-run being necessary.

A further difference noticed in the labs is the manner by which they label the viles for analysis. In 3 of the hospitals a separate independent lab label was attached to each vile, which was subsequently linked to the hospital information system by scanning in the lab label. This task is necessary at the reception for each of the labs.

In Beaumont however the LIS uses the same label as is issued and put onto the vile in the ward itself. This reduces the amount of printing necessary, and one label does all systems. However this is not without its own issues, before

tightening up on the vile acceptance procedure, viles would be labelled on the ward in any kind of way and handed down to the lab in all kinds of stated. As the analysers are very sensitive to the positioning of the labels on the viles, they must placed straight on the vile so the scanner has adequate room to scan, the staff were spending some time each day either re-bar-coding viles, or if they got through to the analyser the staff would end up getting reports for viles that are not linked to the patients details, and is flagged on the analyser as an error for unread barcode label. Now all labels are 100% checked prior to analysis to ensure all labels are legible.

The main limitations outdated systems, similar to the BHIS, as the main operating system is that it's a legacy system and hence its very old-fashioned. It does not have the capabilities of many of the more modern systems. For instance it cannot be allocated to any end users in terms of GP's. Therefore it is not realistic to incorporate any kind of modernisation of these systems; it would be more realistic to build an entire new system.

The BHIS was built nearly 20 yrs ago, and although patients haven't changed over these years, the capabilities of technology have drastically. Therefore older systems in healthcare today were not built in order to accommodate either internet access or even the possibility of a portal to the net.

In order to change this it would be extremely expensive, and would also have to undergo an extensive and exhausting qualification period. A serious issue with these types of legacy system are that when they were built, a guarantee of support from the manufacturer was only given for a certain time period, of which it is vastly approaching. The hospital itself then gets caught up in the dilemma of whether to stick out the period with the existing system and hope for the best, after which point your at a crisis situation where you have to simple buy off the shelf in a hurry and may not be tailor made to your particular needs/requests, or spend extensive resources in terms of time and money researching multiple possibilities and qualifying it over a certain time frame as the other system is in its wind-down stage.

Chapter 6 Conclusions/Recommendations

Through his research a deeper understanding into to hospital laboratory has been gained. Data flow charts were established for each of the four chosen hospitals, and compared.

Research was also carried out into the history of IT within the hospital domain itself, and particularly the laboratory. Through this research it has been established where in the lab that IT could be used and the potential benefits it can bring to the processes.

From this project the potential benefits from IT in the lab can be summarised into three areas:

- Entering in of patient details from current GP paper based ordering system
- Great QC measures in order to constantly monitor the lab and highlight areas of potential savings in terms of time and money
- The integration of the multiple independent PC's/Analysers and software packages that currently all function independent of one another

It has to be noted however that no matter how many studies are carried out depicting the beneficial things computers can achieve, the physical implementation process is one of the most critical and least publicised aspects of using a clinical lab system.

From the research it was found that even though there is a niche in the market for a specific type of software package, once made available for use, it is not always successful. This can be seen with the lack of interest, and lack of uptake, to-date in fully implementing the HealthLink software. In this research only the laboratory manager's opinions were taken into account. In comparison to this, GP's that are users and non-users of the HealthLink software could be interviewed and their opinions compared.

Further research in a similar domain could look into the potential of designing a Laboratory information system that incorporates all or some of the findings

in this project. The stages necessary in qualifying and implementing this could also be investigated. Further work could be carried out into the possibilities of changing the way the labs run at the moment, and incorporating some of the findings in this project. This would have to look at the attitudes the lab and hospital personnel have to change of this extent, and also the many factors that influence such a change from taking place.

A further project could also be to analyse how the data that is reported from the lab, i.e. the analyser results, are actually utilised. Many requests in the Lab, especially in the haematology lab, seem to be for full blood counts instead of anything specific. There may be a means of reducing the complexity of analysis carried out by screening what data is requested, which is actually needed and more importantly what information is used.

The limitation of this project is in the fact that only one section of the lab was researched, the haematology section. Similar analysis would be beneficial in the other areas of the lab also. Possibly there would be an overlap in the information and you may find that the potential benefits of IT in the lab as described in this research may infact be less specific and relate to the entire lab.

Chapter 7 Appendices

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Appendix 2: Lab Questionaire

Interview with Lab managers for M.Sc Health Informatics project

⇒ What is the data flow from point at which blood is removed from patient to analysis of sample and report/result being issues?

⇒ What is the turnaround time for in-house blood sampling and what are the major delaying factors?

⇒ How are the samples gathered in the lab and sorted? What is the breakdown of sampling, i.e. % GP samples, % in-house samples and % outpatient's samples?

⇒ Are all the lab areas electronically linked of independent of each other, i.e. from one lab can u access results from another lab?

⇒ What is the volume of sampling through biochemistry each year?

⇒ What QC is carried out on either the analysers themselves or the lab, i.e. efficiency monitoring, instrument usage, idle time etc?

⇒ Is the date flow for GP's/outpatient samples any different from in-house samples? If so, how?

⇒ Is there any duplication of work within the lab, e.g. manual entry of patient details onto lab system must be done in each individual lab, where one point of entry would suffice?

⇒ Which reports are printed and which are stored electronically and for how long? What is the reasoning behind the different storage methods?

⇒ How many admin staff work manually entering data from GP's/outpatient request forms?

⇒ Do you use any GP electronic requesting system, e.g. Ordercoms?

⇒ If so, what are the benefits/limitations of such a product?

⇒ Do you use any form of middleware in the lab?

⇒ If so, what are the benefits/limitations of such a product?

Appendix 3: List of Informants

- Mr. Peter Gaffney,

Haematology Lab Manager,
The Adelaide & Meath Hospital Dublin,
Incorporating
The National Children's Hospital
Tallaght
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