Intelligent Software for Medical Diagnosis and Treatment

3YP: Design Project – Diagnosis and Treatment of Sexually Transmitted Infections

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Abstract

The purpose of this report is to introduce a prototype of a web application that will support the process of diagnosing and treating sexually transmitted infections (STIs). This is done in a system containing three main parts; there is a patient application, a database and a doctor application. A general overview of the system can be seen in Figure 1.1.

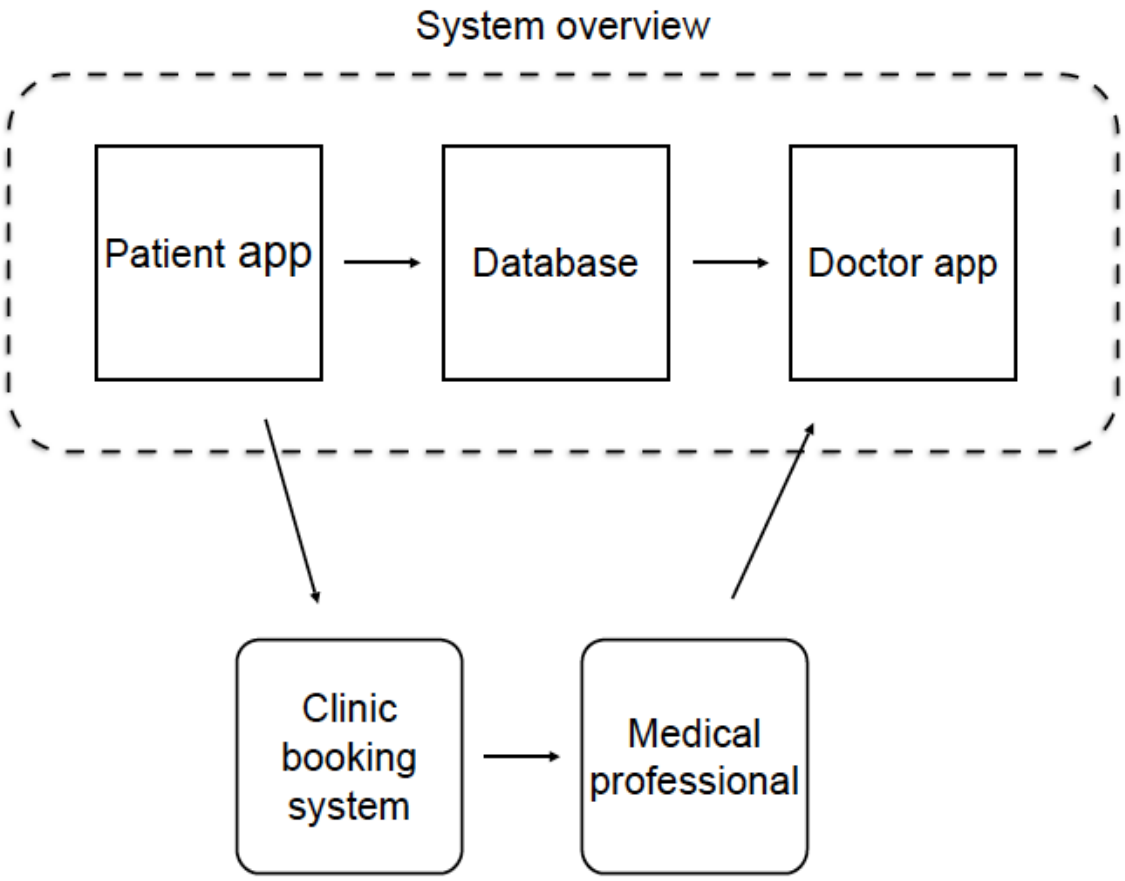

Figure 1.1 Overview of system for diagnosis and treatment of STIs

The first stage of the system is a patient application where anyone who is concerned about STIs can take a short questionnaire about symptoms and other conditions. This patient interface has been designed in the form of a website which can run both on a desktop or a mobile device. If there is any reason to get tested, the application will refer the patient to the booking system of the relevant clinic and store patient information in a database. The database is written in MySQL and communicates with the doctor application through an XML

document that defines the mapping between the database and Tallis, the decision-making program utilised in the doctor application. The information on the database will be accessed when a medical professional uses the doctor application, which provides decision support throughout the process of diagnosis and treatment of STIs. Specifically, the current version of the system deals with chlamydia, gonorrhoea and genital herpes, which are some of the most common sexually transmitted infections.

Since this system deals with sensitive personal information, security is an issue in need of careful consideration, particularly when it comes to online communication and storage on the database. Encryption is investigated in this report and it is concluded that the best method of encrypting data sent to and from the database it to use Public Key Encryption. Furthermore, it is found that it is desirable to purchase Certification Authorities in order to guarantee online security. In addition to protecting the information from being accessed by the wrong person, the information on the database also needs to be backed up to avoid loss of data. After considering different alternatives it is concluded that the best method for database backup for this system is the use of differential backup. It is also concluded that the entire application should be hosted by renting server space from a third party because this provides benefits in terms of scalability, easy maintenance and reduction of risks.

Investing in a system such as this comes with several benefits. The amount of nurse time per patient is significantly reduced, treatment will be consistent and in accordance with relevant guidelines, and the patient experience will improve as instead of having to personally explaining their symptoms the medical professional will already have this information when the patient arrives at the clinic. This will hopefully lead to more patients using the services of the clinic. However, before this system can be launched some more development needs to be done. The total cost of introducing the system is related to the number of medical centres involved such that the cost per clinic reduces with the number of clinics. This means that the primary target market is larger chains of clinics such as NHS or private chains of health clinics.

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1 Medical Background: Creating Patient Pathways for Diagnosis and Treatment of Sexually Transmitted Infections

This section outlines the medical research and consequent decisions that have been made to ensure the application delivers reliable and efficient diagnosis and advice in a clinical setting. The design phase contains pathways for only the 3 most common STIs in the UK but if deployed beyond design phase would include a larger number.

1.1 Introduction to the creation of care pathways

The pathways have been developed from NICE (National Institute for Health and Clinical Excellence (1)) and SIGN (Scottish Intercollegiate Guidelines Network (2)) guidelines. Using two institutions' findings gave assurance that only non-contentious and widely recognised decisions have been incorporated into our application. It should be noted however that the pathways, like the guidelines, may not cover every eventuality, and each patient's individual circumstances need to be taken into consideration by the doctor when a treatment is decided upon. The pathways are designed to aid a doctor's decision and are not intended to replace them.

Ultimately, the pathways will be converted into Tallis (details of why Tallis has been chosen as the software platform are outlined in 3.1 Tallis and PROForma) such that the decisions can be automated by the software. A logical approach would therefore be to represent these pathways as flow-charts with further information included alongside. The flowcharts highlight clearly which decisions the software needs to make and simplifies the work of conversion for the software specialist (Linda Perkio).

1.2 Chlamydia pathway

The flow-chart and accompanying information provided overleaf are the result of extensive research from these NICE and SIGN guidelines and cover the decisions to be made for the vast majority of patients undergoing Chlamydia diagnosis and treatment. NB: Females

suffering from Pelvic Inflammatory Disease (PID) need to follow a separate pathway from the standard one presented overleaf. This pathway has been created but not included in the report as the general layout is identical to the one presented and the report will not be enhanced by including an extra two pages for this separate pathway.

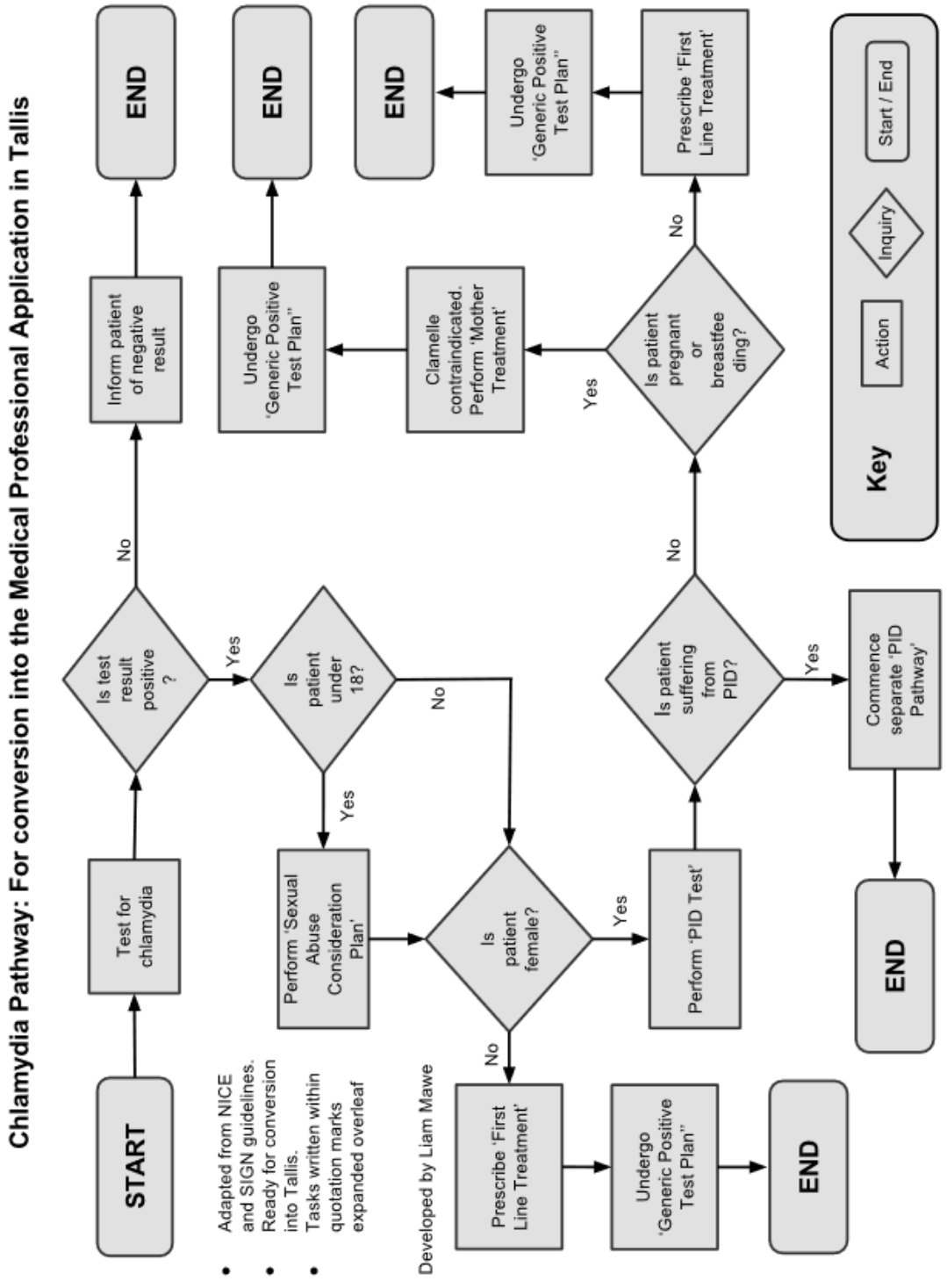


Figure 1.1 Flow chart provided to software specialist for conversion into Tallis.

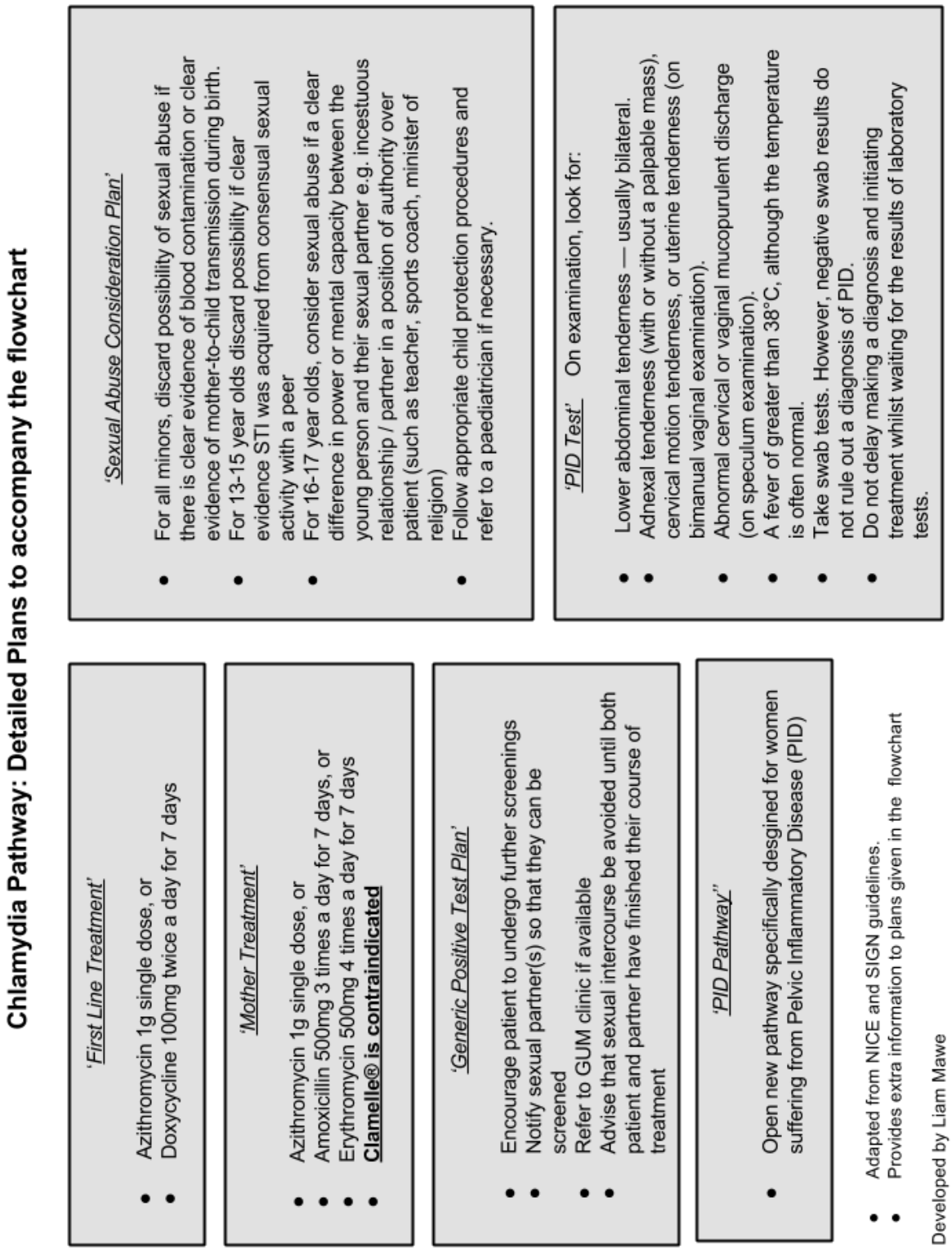


Figure 1.2 Accompanying information for Chlamydia flowchart

1.3 Herpes pathway – diagnosis and treatment

The herpes flowchart has been developed from the NICE and SIGN guidelines. An accompanying sheet gives further details for treatment.

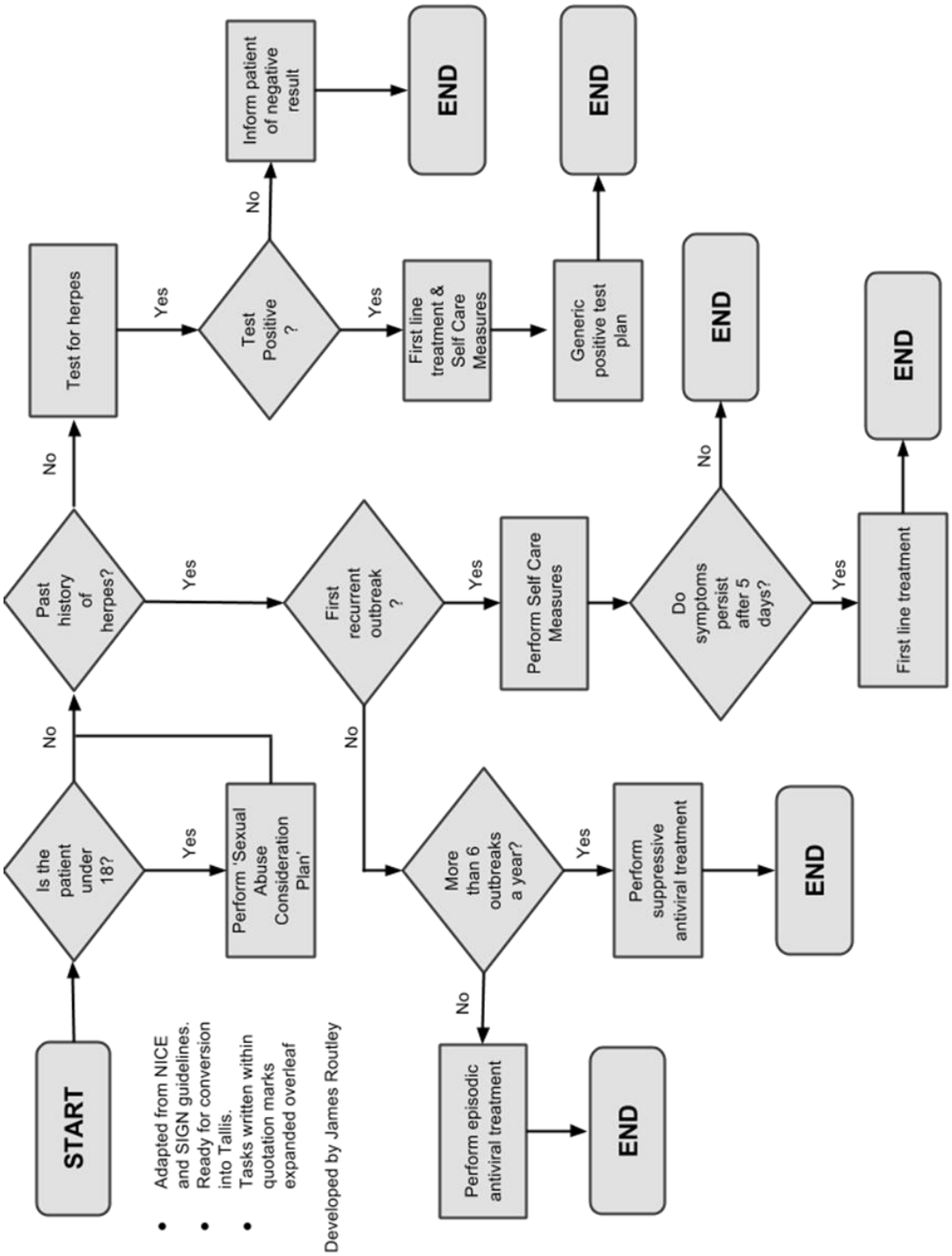


Figure 1.3 Herpes pathway flowchart provided to software specialist for conversion into Tallis

Herpes Pathway: Detailed Plans to accompany the flowchart

'First Line Treatment'

- Prescribe oral aciclovir (200 mg five times a day) within 5 days of the start of the episode or while new lesions are forming. Continue for 5 days, or longer if new lesions are still forming while on treatment.

'Generic Positive Test Plan'

- Encourage patient to undergo further screenings
- Notify sexual partner(s) so that they can be screened
- Refer to GUM clinic if available
- Advise that sexual intercourse be avoided until both patient and partner have finished their course of treatment

'Sexual Abuse Consideration Plan'

Although rare, consider the possibility of sexual abuse in any child or young person with genital herpes, particularly in the following circumstances:

- The child is younger than 13 years of age, unless there is clear evidence of mother-to-child transmission during birth, or of blood contamination.
- The young person is 13 to 15 years of age, unless there is clear evidence of mother-to-child transmission during birth, blood contamination, or that the STI was acquired from consensual sexual activity with a peer.
- The young person is 16 to 17 years of age and there is no clear evidence of blood contamination or that the STI was acquired from consensual sexual activity *and* there is a clear difference in power or mental capacity between the young person and their sexual partner, in particular when the relationship is incestuous or with a person in a position of trust (such as a teacher, sports coach, minister of religion) *or* there is concern that the young person is being exploited.

Adapted from NICE and SIGN guidelines.
Provides extra information to plans given in the flowchart
Developed by James Routley

Figure 1.4 Accompanying information for herpes flowchart

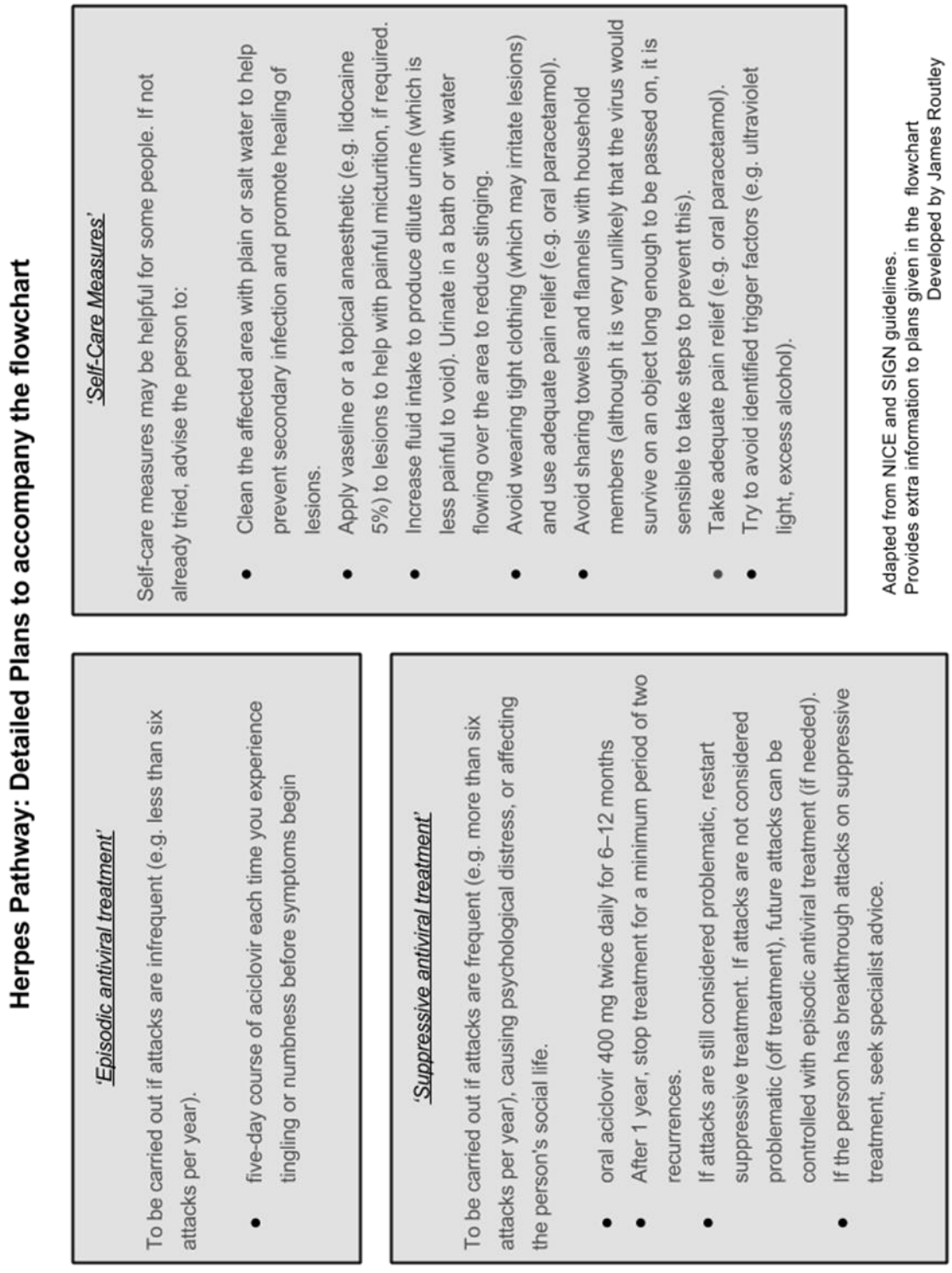


Figure 1.5 Further accompanying information for herpes flowchart

1.4 Gonorrhoea pathway

The gonorrhoea flowchart has been developed from the NICE and SIGN guidelines. An accompanying sheet gives further details for treatment.

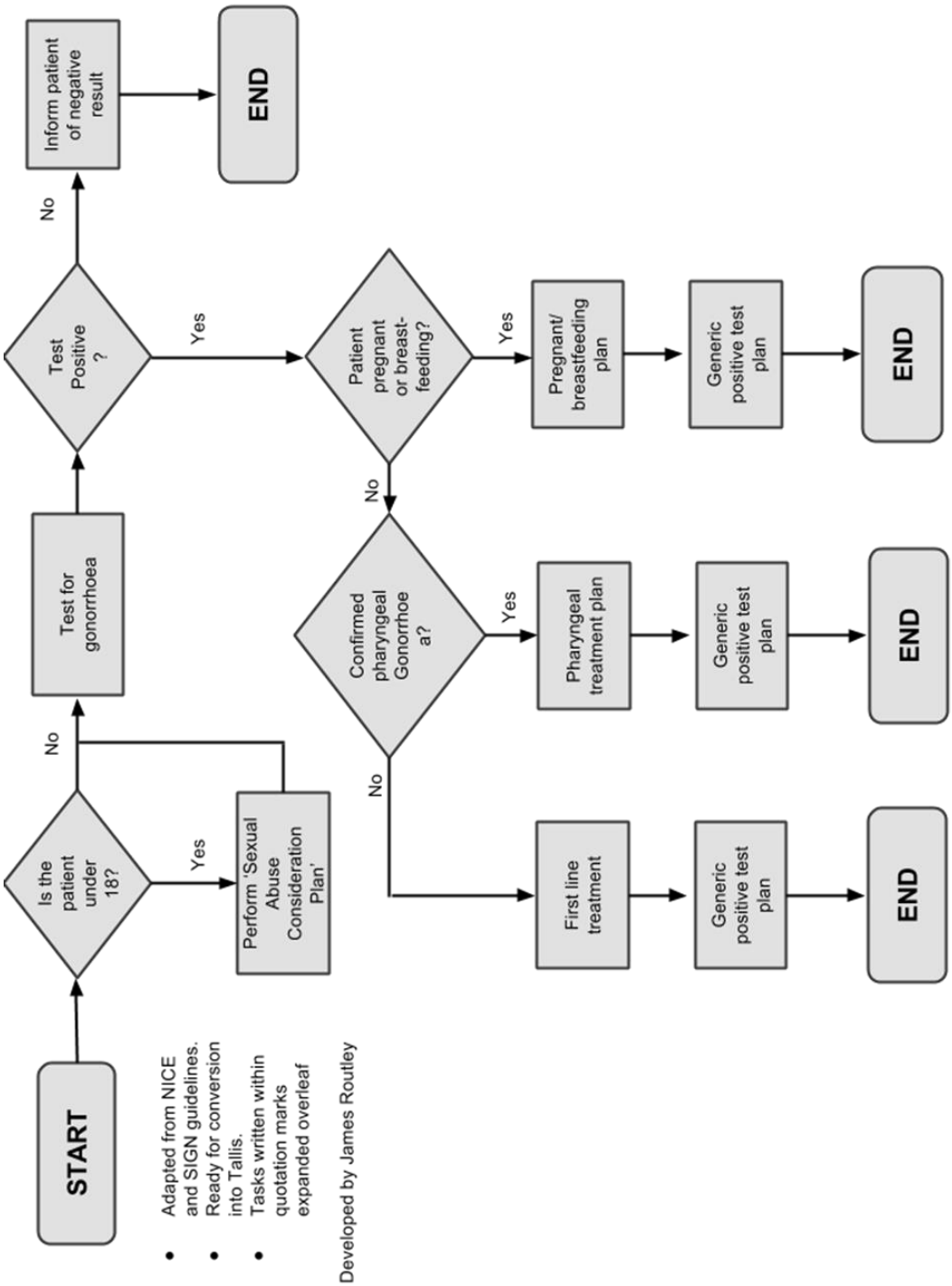


Figure 1.6 Gonorrhoea pathway flowchart provided to software specialist for conversion into Tallis

Gonorrhoea Pathway: Detailed Plans to accompany the flowchart

'*First Line Treatment*'

- Ceftriaxone 500 mg intramuscular (IM) injection as a single dose, *plus* azithromycin 1 g orally as a single dose.
- If an IM injection is contraindicated or refused, offer cefixime 400 mg orally as a single dose, *plus*azithromycin 1 g orally as a single dose.
- If cephalosporins are contraindicated (for example the person has a true allergy to penicillin-type antibiotics), consider a fluoroquinolone (ciprofloxacin 500 mg, single oral dose or ofloxacin 400 mg, single oral dose) *plus* azithromycin 1 g, single oral dose.
- *Only* prescribe a fluoroquinolone if the infection is known to be sensitive to fluoroquinolones (that is, culture and sensitivity results are available for the person or recent sexual partners).
- If these regimens are unsuitable or unavailable, contact the local microbiology or genito-urinary medicine clinic for advice.

'*Sexual Abuse Consideration Plan*'

Although rare, consider the possibility of sexual abuse in any child or young person with genital herpes, particularly in the following circumstances:

- The child is younger than 13 years of age, unless there is clear evidence of mother-to-child transmission during birth, or of blood contamination.
- The young person is 13 to 15 years of age, unless there is clear evidence of mother-to-child transmission during birth, blood contamination, or that the STI was acquired from consensual sexual activity with a peer.
- The young person is 16 to 17 years of age and there is no clear evidence of blood contamination or that the STI was acquired from consensual sexual activity *and* there is a clear difference in power or mental capacity between the young person and their sexual partner, in particular when the relationship is incestuous or with a person in a position of trust (such as a teacher, sports coach, minister of religion) *or* there is concern that the young person is being exploited.

Adapted from NICE and SIGN guidelines.
Provides extra information to plans given in the flowchart
Developed by James Routley

Figure 1.7 Accompanying information for gonorrhoea flowchart

Gonorrhoea Pathway: Detailed Plans to accompany the flowchart

'Pharyngeal Treatment'

- Ceftriaxone 500 mg intramuscular (IM) injection as a single dose, *plus* azithromycin 1 g orally as a single dose.
- If an IM injection is contraindicated or refused, offer oral cefixime (400 mg loading dose, followed by 200 mg twice a day for 3 days) *plus* azithromycin 1g orally as a single dose.
    - Note this regimen is off-label and is recommended on the basis of expert opinion rather than trial-based evidence.
- If cephalosporins are contraindicated (for example the person has a true allergy to penicillin-type antibiotics), consider a fluoroquinolone (ciprofloxacin 500 mg, single oral dose or ofloxacin 400 mg, single oral dose).
    - *Only* prescribe a fluoroquinolone if the infection is known to be sensitive to fluoroquinolones (that is, culture and sensitivity results are available for the person or recent sexual partners).

'Pregnant or Breastfeeding Plan'

- Ceftriaxone 500 mg intramuscular (IM) injection as a single dose, *plus* azithromycin 1 g orally as a single dose.
- If IM ceftriaxone is unavailable or unsuitable, offer cefixime 400 mg as a single oral dose plus azithromycin.
- Do not prescribe a fluoroquinolone for a woman who is pregnant or breastfeeding. Seek specialist advice if a cephalosporin is contraindicated, for example if the woman has a true allergy to penicillin.

Adapted from NICE and SIGN guidelines.
Provides extra information to plans given in the flowchart
Developed by James Routley

Figure 1.8 Further accompanying information for gonorrhoea flowchart

1.5 Required patient information

Table 1.1 is a summary of all the information we need to gather from patients.

Personal information is gathered means of identifying and contacting patients, symptoms are used in the diagnosis process and background information is gathered to reveal statistical trends in the age, sex, ethnic, sexuality, religion and abled distribution of STIs.

Table 1.1 List of patient information required

Personal Information	1. Name 2. Name you would like to be called in the clinic 3. Date of Birth 4. Sex 5. Country of Birth 6. Address 7. Phone number (home) 8. Phone number (mobile) 9. Email address 10. Where you would like to be contacted 11. Contact details of your GP
Symptoms (Female)	1. Bleeding after sex 2. Bleeding between periods 3. Bleeding after sex 4. Blisters in the genital area 5. Blisters on the cervix (lower part of the womb) 6. Burning or tingling sensation around the genital area 7. Different vaginal discharge 8. Feeling generally unwell

	9. Heavier period than usual 10. High temperature 11. Increased vaginal discharge 12. Itchy vagina 13. Pain during sex 14. Pain in the lower abdomen 15. Pain when peeing 16. Red vagina 17. Swollen vagina
Symptoms (Male)	1. Blisters in the genital area 2. Burning or tingling sensation around the genital area 3. Discharge from the penis tip 4. Feeling generally unwell 5. High temperature 6. Itching penis tip 7. Pain in the testicles 8. Pain when peeing 9. Peeing more frequently than usual 10. Rectal pain 11. Swollen Testicles 12. Thick Penis discharge
Background Information	1. Ethnic group 2. How you were referred to the clinic 3. Sexuality 4. Religion 5. Whether you consider yourself to have a disability

1.6 Expansion of pathways to include complete package of STIs in the UK

The prototype currently only contains pathways for Chlamydia, Herpes and Gonorrhoea. The complete application beyond design phase will also need to include:

1. Genital Warts
2. Hepatitis B
3. HIV / AIDS
4. Pubic Lice
5. Syphilis (primary and secondary)

The realisation of the Chlamydia pathway from research through to completed Tallis pathway will be broken down and analysed. This will then serve as a reference point to estimate the time and cost of expansion of this application.

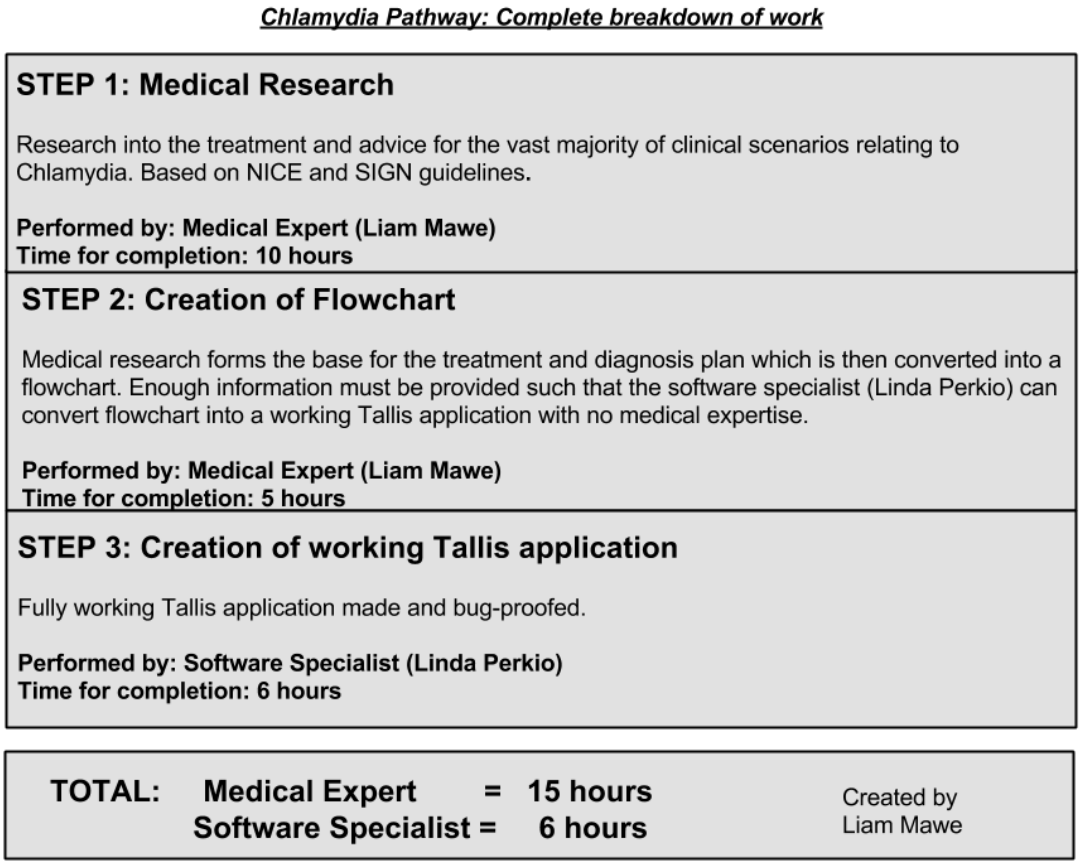


Figure 1.9 Complete breakdown of work for creation of Chlamydia pathway

The pathways for genital warts, Hepatitis B, pubic lice, syphilis (primary) and syphilis (secondary) would all contain a similar depth of treatment and advice to that of Chlamydia. Conversely, the HIV / AIDS pathway is more complex with data in the treatment and advice guidelines being considerable larger. Comparing the NICE and SIGN guidelines for HIV / AIDS with those of Chlamydia indicates that the HIV / AIDS pathway would be approximately 3 times more expensive in both the medical expert's and the software expert's time.

The total extra hours needed to expand the application will therefore be equal to roughly 8 times the hours needed to create the Chlamydia pathway and amount to:

120 hours of the medical expert + 48 hours of the software expert

NB: '1. Medical Background: Creating Patient Pathways for Diagnosis and Treatment of Sexually Transmitted Infections' involves work from Liam Mawe and James Routley. Headers indicate the author of each section.

2 Patient Interface

This section presents the design of the patient website in terms of functionality and aesthetics. Hosting and other technical requirements are discussed in section 4 on page 74. The patient interface has been designed under the assumption that the application will be implemented by the NHS and so follows NHS branding guidelines. The proposed design can be easily adapted for use in the private health sector simply by changing the logos and changing the main colour if necessary.

2.1 Desktop access

In this section, 'desktop' refers to both traditional desktop computers and laptop computers. Mobile devices such as tablets and smartphones are discussed in section 2.2 on page 35.

2.1.1 Audience

To decide on a suitable website design, it is necessary to identify the core segments of the population who will be using it. In this case it is those most likely to catch an STI.

Table 2.1 Age of patients diagnosed with an STI in the UK, 2008-2012 (3)

STI	Patient < 25 Years Old	Patient < 35 Years Old
Chlamydia	70%	92%
Gonorrhoea	43%	77%
Syphilis	17%	50%
Total	66%	90%

Table 2.1 shows that most people diagnosed with an STI are under the age of 25. Increasing the age range to those under 35 includes the vast majority of diagnoses. The implication of this is that the website should be targeted towards young adults. It can be assumed that

most users are experienced with the internet and are comfortable navigating a page and filling in a form.

Based on this target audience, the patient website will have a simple layout and not be saturated by text. The design will be modern and will include pictures to help break up the text. Although this may seem like standard design procedure, analysis of existing sexual health websites in the following section shows that existing websites often fail to meet these very basic criteria. Therefore, it is necessary to focus on creating a patient website which is simple yet effective.

2.1.2 Existing Websites

The NHS website has some guidelines for creating a website with NHS branding (4). These guidelines limit the colours which can be used and specify the font to be Arial or Helvetica.

The NHS website (5), the Oxfordshire GUM clinic website[1] (6), and the Buckinghamshire sexual health website (7) are examples of websites similar to the one being designed. The good and bad points of these websites can be analysed in order to make design decisions about the patient website.

2.1.2.1 Points to keep

- **Content in the centre of the screen**
    - All three websites have the page content aligned in the centre. This allows the site to look good on both widescreen and normal monitors.
- **Banner at the head of the page containing logos**
    - This is another design feature that all the websites share. The main website logo is on the left at the top of the page and, for the Oxfordshire and Buckinghamshire sites, the NHS logo is displayed at the top on the right. For consistency, and

[1] The Oxfordshire GUM clinic website was updated around 3/4/14 after the writing of this section of the report. Updates include a new logo, the addition of some purple colouring, and, interestingly, the expansion of header and footer banners to the full width of the page, similar to the website designed in this report. The desktop version of the new website is similar to before so the analysis remains valid, however the mobile version has changed substantially. This is discussed in section 2.2.1 on page 21.

maintaining the assumption that the application will be implemented by the NHS, the patient website will share the same design.

- **Section links at the head of the page**
    - All three websites have a banner at the head of the page containing links to sections of the website. This is a standard and effective feature of many websites and will be used for the patient website to promote simple page navigation.
- **Banner at the foot of the page**
    - The Oxfordshire website has a basic banner at the foot of the page containing links to the disclaimer, privacy policy, and sitemap, as well as copyright information. This looks better than the NHS page, which has a thick footer saturated with links. The Buckinghamshire page has no footer, which leaves the page looking bare.

2.1.2.2 Points to be improved or removed

- **The website will use one main colour, with the remaining colours being greyscale**
    - The NHS website uses blue, orange, green, red, and black fonts all on the same page. Background colours include black, white, grey and blue (see Figure 2.1 for an example). The Oxfordshire website uses green, white, and orange backgrounds with black text, but there is some red text used for emphasis. Both sites use colour gradients in the background of some headers or buttons. By using one main colour supported by greyscale, similar to the Buckinghamshire website, the patient website will look modern and professional. This aligns with attracting our target audience.
- **The home page will be simple and uncluttered**
    - The home pages on the NHS and Oxfordshire websites are overloaded with text and links. This makes them dense and unattractive. The patient website will have only important information on the home page – a brief introduction and a link to the appointment booking page. This will help users to find what they are looking

for quickly after arriving at the page. A simple website will also make it easier to use on a mobile device – see section 2.2 on page 35 for full mobile design analysis.

- **Section links will have drop-down menus for subsection links**
  - The Oxfordshire and Buckinghamshire sites do not make use of drop-down menus and the drop-down menus on the NHS website are long. Drop-down menus are an effective way for a user to navigate a website – especially as the patient website will not have a huge number of pages.
- **Section pages will include subsection links to one side and make efficient use of space**
  - Another way of displaying subsection links is to have them to the side of the section page. Figure 2.1 shows how this is done badly on the NHS page; the subsection links take up over 1/3 of the width of the page but only take of a tiny fraction of the height. The page text is forced into a long, narrow area as all of the space below the links is wasted.

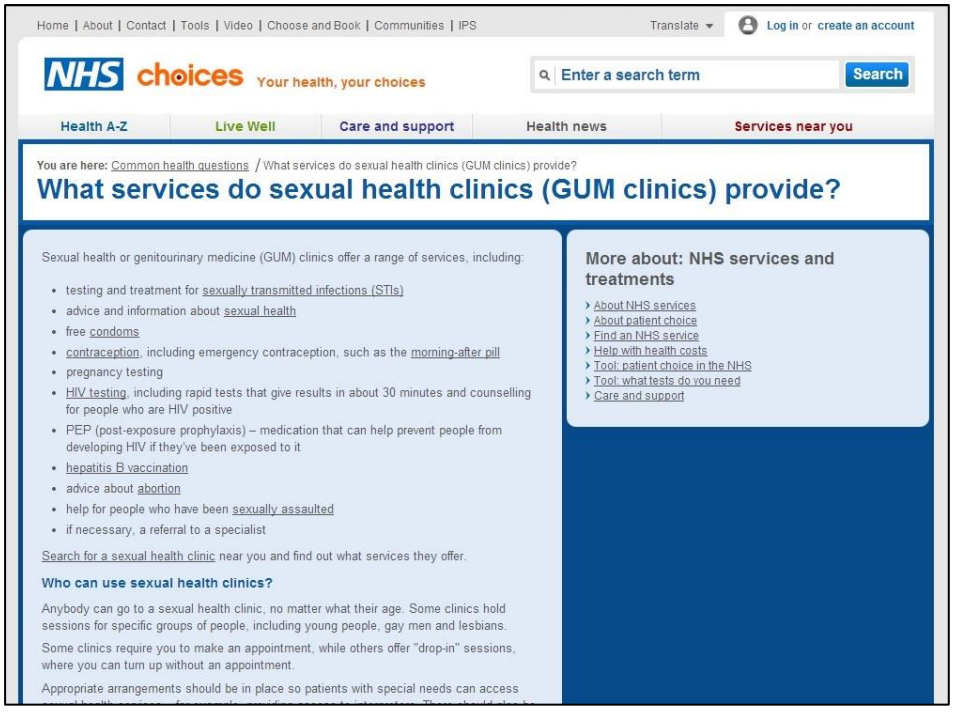


Figure 2.1 An example of the NHS website, showing inefficient use of space

- The Buckinghamshire website (Figure 2.2) has subsection links which only take up 1/4 of the page content. These links stand out much more than the NHS ones and also contain sub-subsection links within them once clicked. The patient website will make use of a similar design.

Figure 2.2 The Buckinghamshire website, showing good use of space and sub-section links

- **Picture slides for sexual health information at the top of the page**
  - Both the NHS and the Buckinghamshire websites have graphics at the top of the page which change automatically after a set amount of time. These help to break up the page and highlight important information. However, the automatic changing can be annoying for a user who is only interested in a particular graphic. Therefore, the graphics will be made manually scrollable with arrows displayed either side of the graphic to indicate this and a navigation bar below the graphic to

indicate the total number of graphics and the number of the current selection. Horizontally scrollable graphics work well with touch screen mobile devices too. Mobile access is discussed fully in section 2.2 on page 35.

- **No 'you are here' bar**
    - The Oxfordshire website has a 'you are here' bar which tells users the name of the page they are currently on. This is unnecessary, especially for a simple website like the one being designed. Since the users will almost all be competent browsing the internet (see section 2.1.1) it can be assumed that they can navigate the page without this bar, which can thus be removed in order to keep the page simple.
- **No 'search' box**
    - The Buckinghamshire website has a search bar near the top of the page. Custom search boxes often provide inefficient ways of searching for information. Instead the patient website has been structured in a strategic way so that it is obvious to users exactly where to find the information they want.
- **The contact section will have Google maps**
    - The contact section for the Oxfordshire site is all text. The Buckinghamshire site includes a graphic, which is a slight improvement. The patient site will have Google maps embedded in the page. This allows users to quickly visualise the location of the clinic without having to read through paragraphs of road directions.

2.1.3 Website functionality

2.1.3.1 Home page

As discussed above, the home page will include a brief overview of the clinic. There will be a sliding graphic at the top of the page to highlight important information. As well as the links in the banner at the top of the page, there will be a link in the body of the page to the 'booking an appointment' section to make it obvious for end users.

2.1.3.2 Visiting the clinic

This section will have all the important information about the process of visiting a clinic. The aim is to provide answers to questions that patients may have. This will include information on confidentiality (including confidentiality for those under 18), time-lines for testing and treatment, and descriptions of the kinds of tests which can be done. To align with the target audience, it is important to keep text concise and easy to read at all times.

There will also be a subsection for information on how to find the clinic so that the patient can find all important location and contact information on one page. It will include the clinic phone number as well as opening times. As specified, it will have Google maps embedded so that users can easily locate the clinic, and can also have information on local busses patients can use to visit the clinic.

2.1.3.3 Booking an appointment

This section provides the key function of the website; to allow patients to fill in registration details and a sexual history online. The data they submit will be stored in a database and used by the Tallis application to help the doctor decide on testing and treatment – there is more detail on these parts in the relevant sections.

The main page of this section will explain to the user that the clinic is implementing a new system for filling in patient information. This is to raise awareness and encourage patients to use the new system. There will be a subsection explaining the advantages of filling in your information online and a subsection for the information form. There will be references and links to the 'visiting the clinic' section where appropriate.

2.1.3.4 Information form flowchart

Figure 2.3 is a flowchart detailing the function of the information form. The entire form is not displayed on the page at once. Instead, basic JavaScript logic is used to determine which part of the form to display next based on user input.

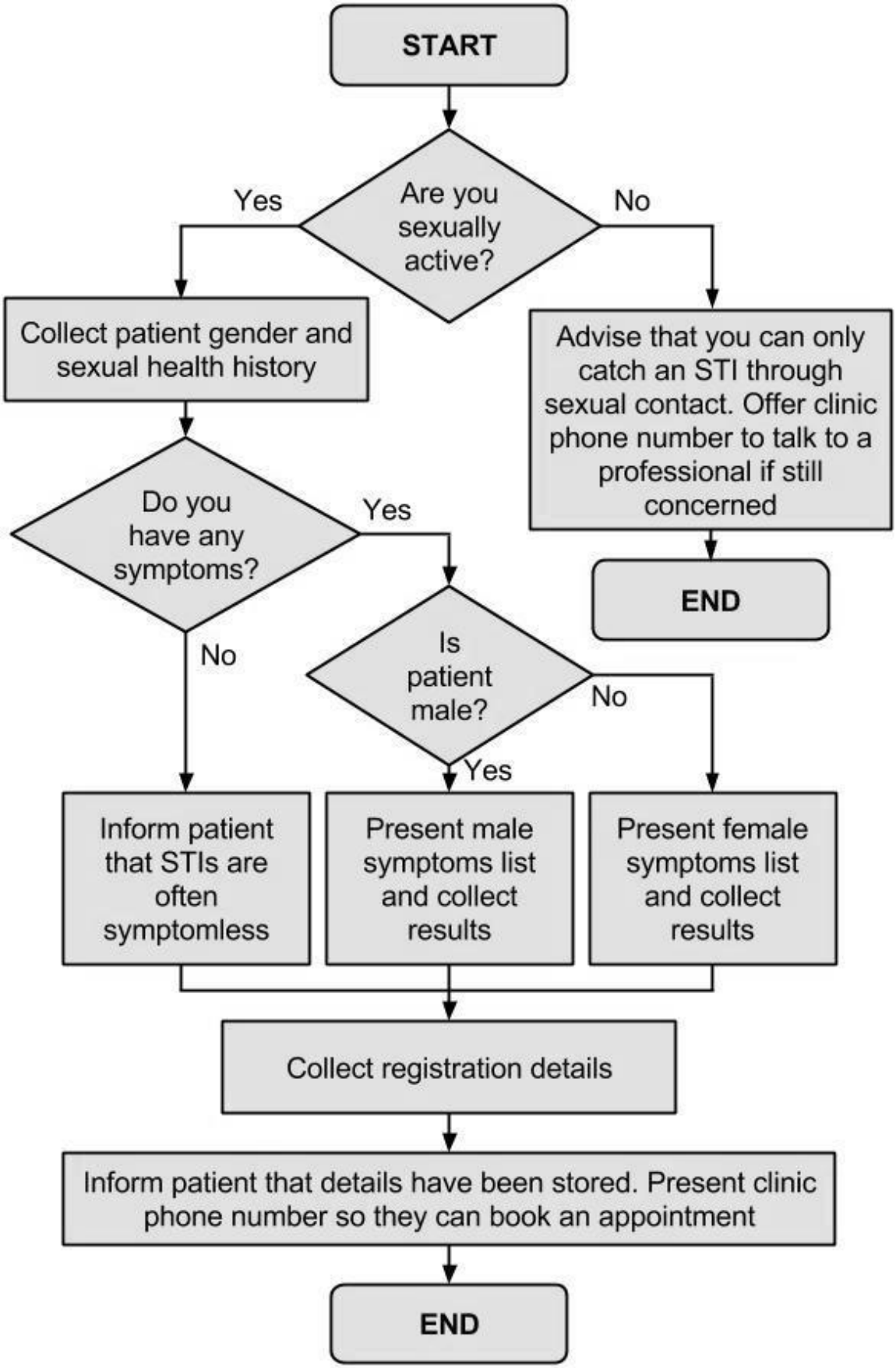


Figure 2.3 Flowchart representing the patient information form

2.1.3.5 Sexual health information

The aim of this section is to provide information about sexual health in general. This includes information on STIs, pregnancy, contraception and can also include information for LGBT and young people.

2.1.4 Desktop website design considerations

2.1.4.1 Minimum screen resolution

The main formatting consideration for a desktop website is the resolution of the screen it is to be viewed on. Figure 2.4 shows usage statistics for desktops in the UK. From this graph, as of March 2014 there are 2.8% of people using an unknown monitor size and 14.4% using size 'other'. These proportions have been relatively steady for the past 12 months so can be assumed to be roughly constant. This means that at least 82.8% of people in the UK are using screen resolutions of 1024x600 or greater. This is probably an underestimate given that some of the resolutions contained in the 'unknown' and 'other' categories are likely to be higher than 1024x600. Based on this information the website content will fit within 1024 pixels. Including a 10% tolerance, the design width is approximately 920 pixels.

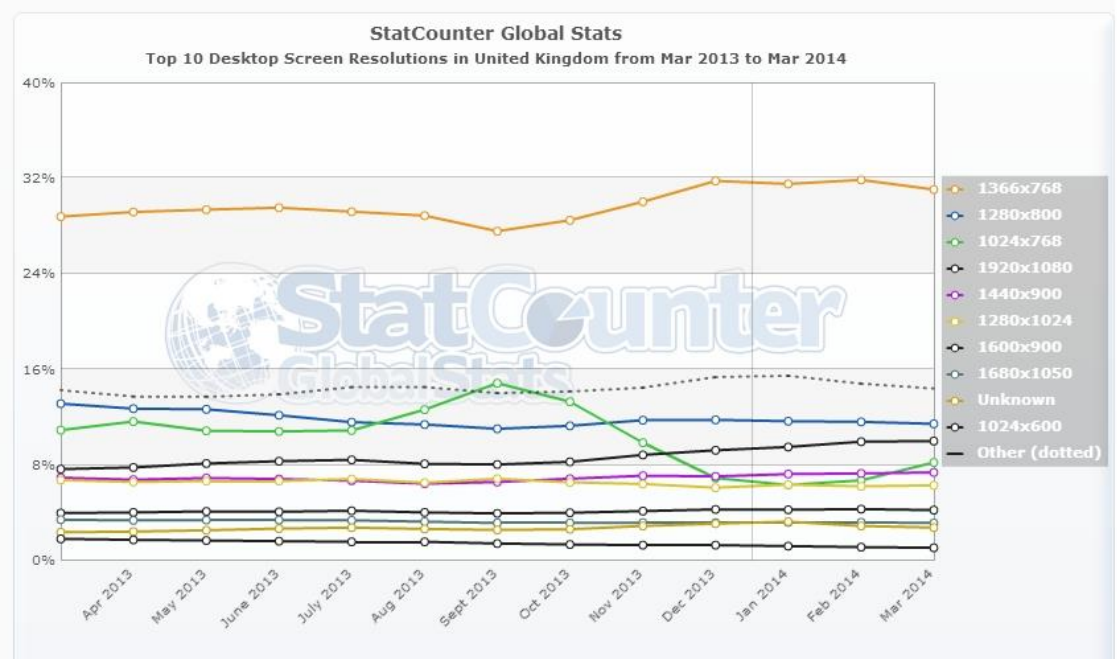


Figure 2.4 Graph of desktop monitor resolution in the UK for the past year (8)

2.1.4.2 Disabled access

Not all of the users of the application will be able-bodied and it is important to make the user website as disabled-friendly as possible. People who are blind can use screen readers – pieces of software that read out the content of websites. For screen readers to be effective the websites that they are reading must be laid out in the correct way.

The website will be written in HTML, which provides tags allowing website developers to label blocks of text as having certain features, such as titles, subtitles, paragraphs, and lists. These tags must be used correctly for screen readers to be effective.

2.1.5 Desktop website design

The patient website can now be designed based on the considerations already discussed and the specification for the functionality. Figure 2.5 shows the design of the home page. The colours chosen are white and NHS blue, with black body text. NHS blue was chosen from the colours given in the NHS branding guidelines so that the page fits with the NHS logo. The font is Arial as set out in the branding guidelines. (4)

The header contains the current Oxfordshire GUM logo, edited from green to blue, alongside the NHS logo. The banner containing the section links and the footer banner expand to the full width of the screen. This is mostly for widescreen users; it helps to add colour and to break up the page.

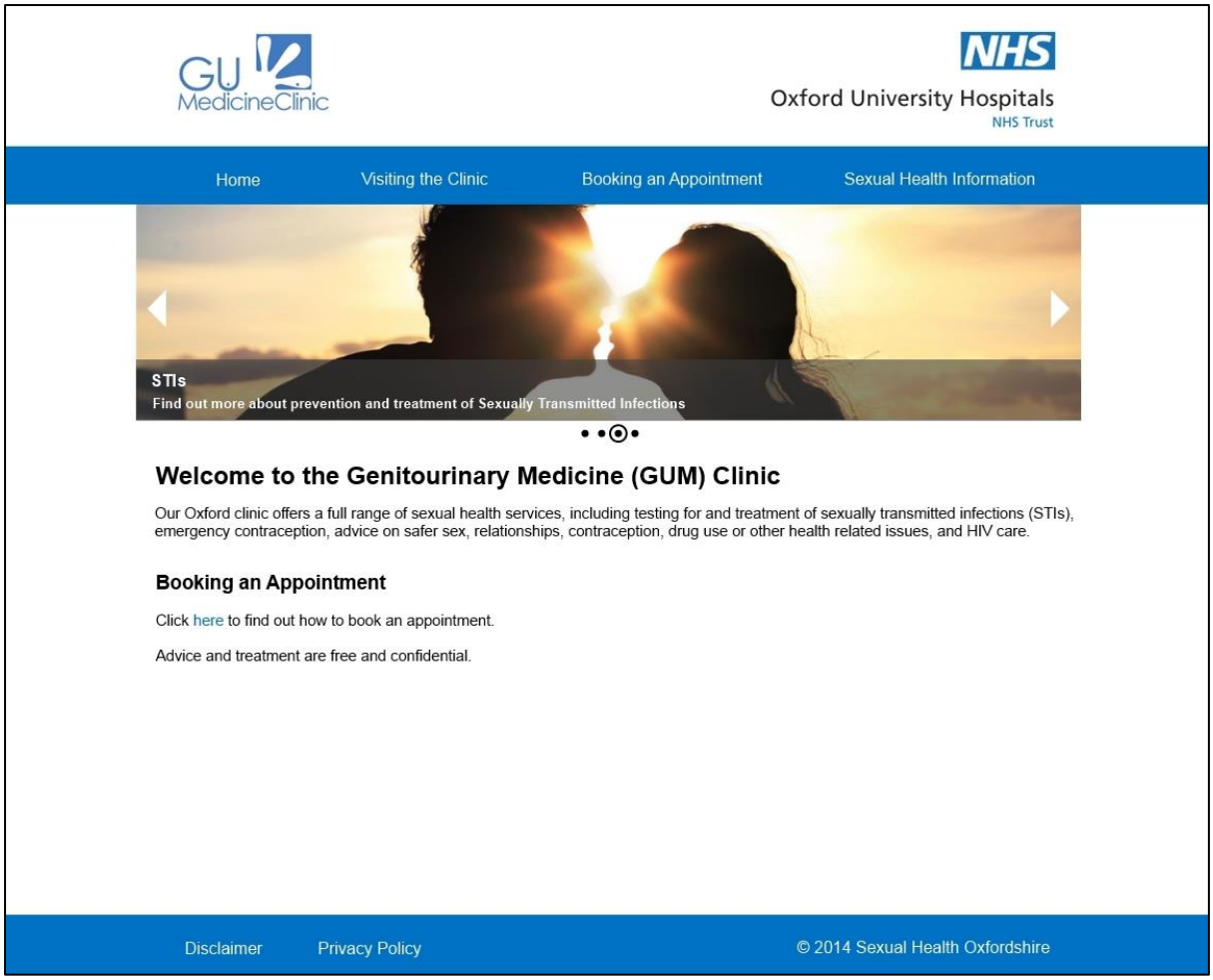


Figure 2.5 Design of the patient website home page

Below the section links banner are the picture slides. The example picture (9) given was chosen because it depicts a physical relationship between two people, it has a central focus, and it is minimal in the colours used. The picture will be a link to the relevant subsection of the website as described in the picture caption. The slightly transparent grey bar along the bottom of the picture helps the text to stand out so it is readable. As shown by the four circles beneath the picture there are four pictures, of which the one shown is the third. The four key areas which will have pictures are 'Confidential Advice', 'Register Online', 'STIs', and 'Contraception'. They are all links to subsections; 'Confidential Advice' links to a subsection within 'Visiting the Clinic', 'Register Online' links to a subsection within 'Booking an Appointment', and the final two link to subsections within 'Sexual Health Information'.

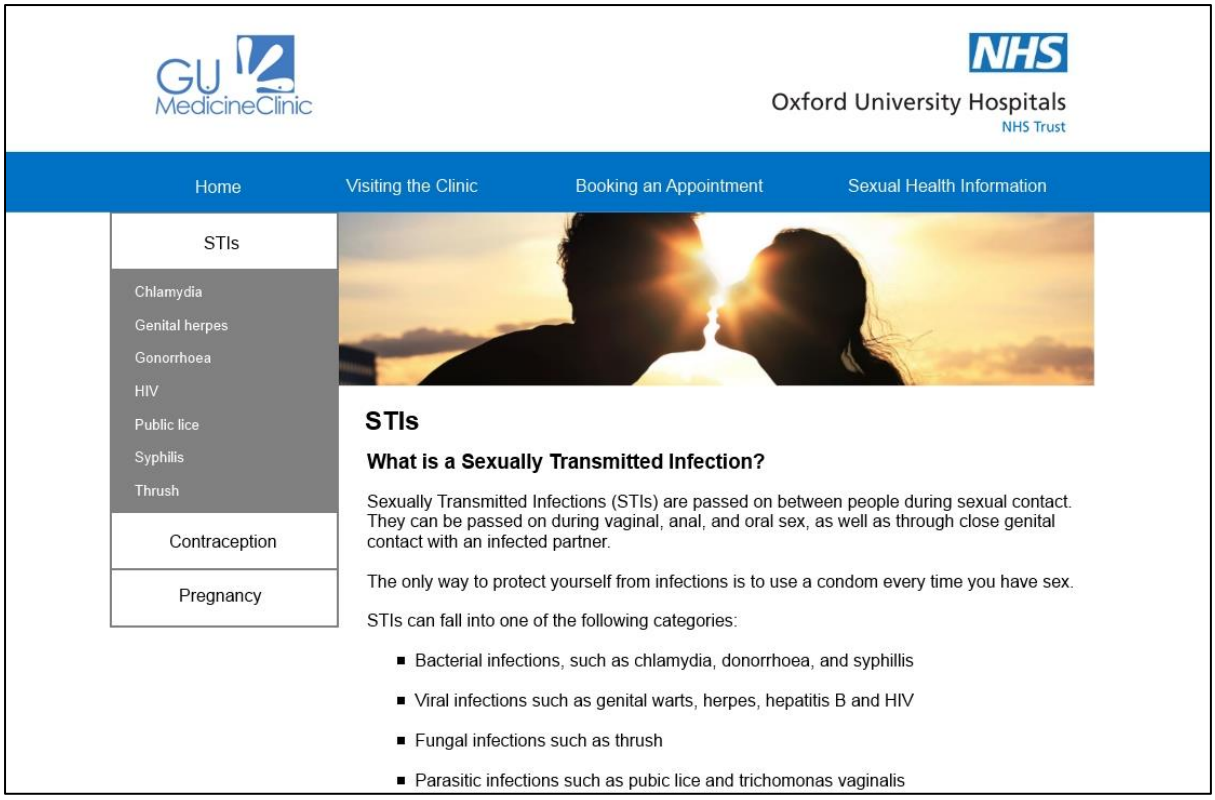


Figure 2.6 Design of the Sexual Health Information page

As specified, the body of the home page contains a brief description of the clinic and a link for information on booking an appointment. The example text given has been copied from the Oxfordshire sexual health website. (6)

Figure 2.6 shows the STI subsection of the sexual health information page. The subsection links are in white on the left of the page. As this is the STI subsection, the STI link has expanded to show the STI sub-subsection links in grey. If, for example, the contraception subsection link is clicked by the user, the grey STI sub-subsection links will contract and a list of the contraception sub-subsections will expand. The example text on this page has been copied from the Buckinghamshire sexual health website. (7)

The rest of the website has been designed based on the same template. Each section and subsection page will have its own unique picture at the top. Sub-subsection pages use the picture from their parent subsection.

2.1.5.1 Information form design

Figure 2.7 shows a zoomed-out version of the online registration subsection page. The page follows the standard template with an example picture at the top (10). There are four pages to the form, which is contained within a grey box. This is consistent with the flowchart in Figure 2.3. There is a button to start the registration process. The first page of the form simply asks the patient if they are sexually active. The second page collects information on gender, age, sexual history, and asks the patient if they have any symptoms. The third page either presents a list of symptoms for the patient to choose from (based on gender) or informs the patient that it is possible to have an STI and not present symptoms, thus it is still important for the patient to visit the clinic if they think they are at risk. The fourth and final page collects contact information from the patient.

This form is equivalent to the current GUM registration form (11) (although patient gender and age will already have been collected so are omitted from this page). Once the form is submitted the patient is informed that their information has been stored and given the phone number of the clinic so they can make an appointment.

There are 'back' and 'next' buttons at the bottom of the form, apart from on the first page where there is no 'back' button and on the last page where the 'next' button becomes a 'submit' button. The current page is indicated by the circles at the bottom of the form, similar to the scrollable graphics on the home page. As can be seen, the page displayed in Figure 2.7 is the fourth page so the fourth circle is highlighted. It is possible to show and hide layers of the form using JavaScript.

JavaScript can also be used for front-end data validation. This will check that the user is entering data into the form and that the data is of the correct format. However there must also be back-end data validation as it is possible to bypass front-end validation. Database security is discussed in section **Error! Reference source not found.**. The main advantage of JavaScript data validation is to improve the user interface by offering instant feedback

when form fields are filled in. The format for each field will be set in the database and the JavaScript used needs to reflect this.

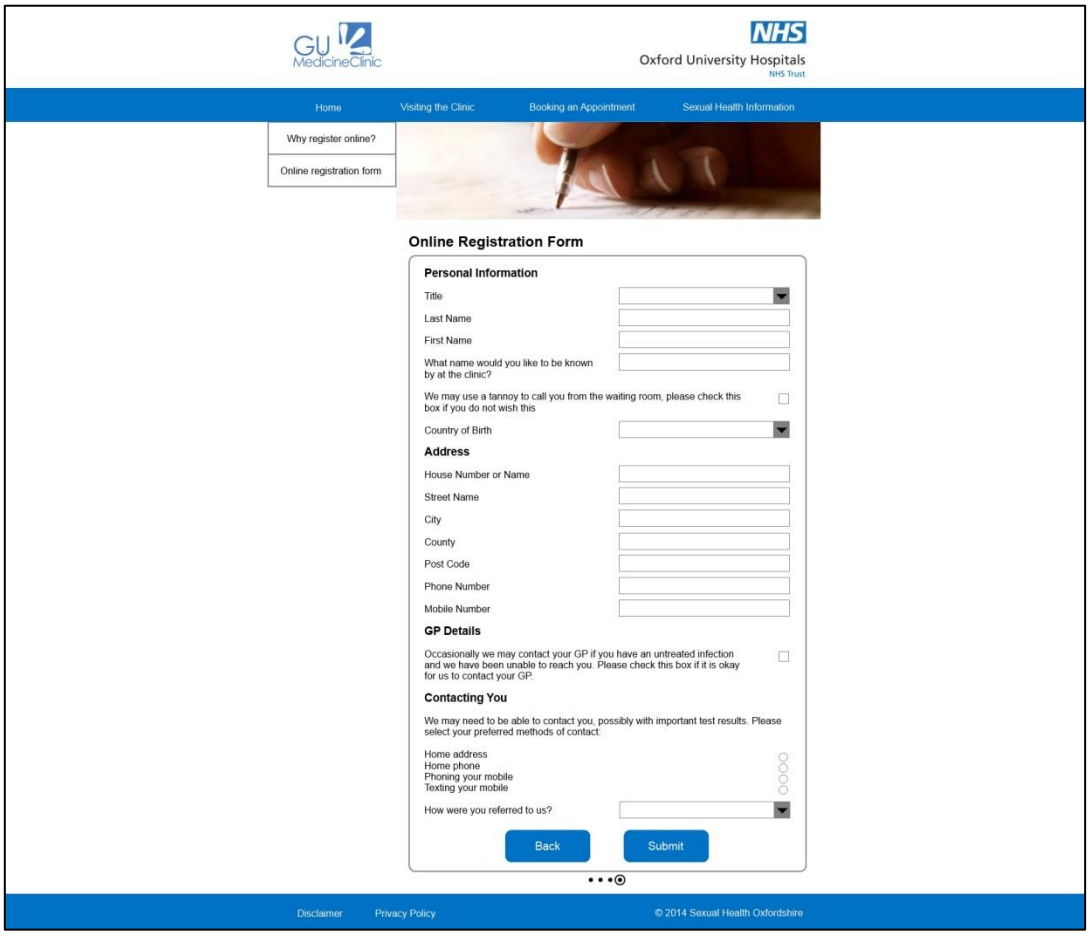


Figure 2.7 The last page of the information form

2.2 Mobile access

Mobile internet use is becoming increasingly popular, especially amongst young adults (the UK has the biggest proportion of 18-24 year old mobile users in the EU5 (12)), so it must be considered when designing a website for this audience. Designing a website which is suitable for mobile use involves considering a range of screen sizes from small smartphones to large tablets; the website must be compatible with all of them.

2.2.1 Existing websites

As of March 2014 the NHS website, the Oxfordshire sexual health website, and the Buckinghamshire sexual health website are not optimised for mobile. The Buckinghamshire site is particularly bad on a smartphone; Figure 2.8 shows that the links banner at the top of the page does not fit and the search bar is partially off the screen. The picture slideshow constantly displays a loading graphic despite the page being loaded.

Figure 2.8 Buckinghamshire sexual health website as viewed from a mobile device

The NHS site is inconsistent. The homepage is identical to its desktop version – this only makes their formatting issues worse. The text is small and hard to read, and in order to navigate the different sections of the website the user is forced to zoom in and scroll to the part of the page which contains the desired hyperlink. Some pages, however, have been adapted for mobile. These are discussed overleaf.

In April 2014 the Oxfordshire sexual health website was updated to a fully responsive website (13). This version is an improvement from the last but there are a number of flaws. The analysis below has been updated to include the new Oxfordshire site.

2.2.1.1 Points to keep

- **Single column for page content**
  - All three websites have the page content in a single scrollable column; this is standard for mobile web design.
- **Single menu button with expandable menu**
  - Condensing the content to a single column implies condensing the menu banner so that the website remains functional. The NHS Chlamydia page (14) and the new Oxfordshire sexual health website achieve this by using a single menu button, indicated by three horizontal lines. The menu expands downwards when clicked, as shown in Figure 2.9.

Figure 2.9 NHS choices chlamydia page with menu button pressed

2.2.1.2 Points to be improved or removed

- **Subsection links will be included in the main expandable menu to reduce clutter**
    - Figure 2.9 shows that the links within the Chlamydia section of the NHS site are not well formatted. It would be better to use a multi-layered toggle menu to access these sections – especially as the patient website is fairly small – in order for the patient website to look good and still be easily navigable.
- **Ensure correct formatting for graphics and embedded objects**
    - The NHS page includes a video which is wider than the width of the screen. It is important to ensure that all content fits the width of the page as it is scaled.
    - Twitter is embedded at the bottom of the new Oxfordshire page above the footer and includes its own scroll bar. It is possible for users viewing the page from a small screen mobile device to get stuck over the Twitter feed and be forced to scroll through all the Twitter content before being able to scroll the main page content again.
- **Adhere to NHS guidelines**
    - The new Oxfordshire site does not adhere to the NHS guidelines about the 'exclusion zone' necessary around the NHS logo. Figure 2.10 shows that there is not enough white space surrounding the logo.
- **Ensure correct break point design**
    - Figure 2.10 also shows that the breakpoint design for the new Oxfordshire site is poor; the 'Oxford University Hospitals' logo overlaps and hides part of the 'Oxfordshire Sexual Health Service' logo (the upper green section is supposed to end at a point) as shown in Figure 2.10. When the page eventually breaks the menu button changes from the version shown in Figure 2.10 to a simple three-line button without the word 'menu' despite the fact that there is plenty of room for the menu button to move into. Correct breakpoint design is important in order for the website to seem professional. Responsive website design and breakpoints are

explained in section 2.2.2.2 on page 39. Full breakpoint design procedure is discussed in section 2.2.3 on page 42.

- **Ensure design consistency with desktop version**
    - The formatting of the header banner is not consistent on the new Oxfordshire site. Figure 2.10 shows it becomes a thick black bar as the page width decreases though the header banner for the desktop version is thin and light grey. It is important for the website to be consistent in order to maintain brand strength.

Figure 2.10 New Oxfordshire sexual health website

By maintaining formatting consistency and following a rigorous breakpoint design procedure, the design given in this report has avoided the issues present in the new Oxfordshire website.

2.2.2 Mobile website design considerations

There are three options which must be considered when designing a mobile website: a separate mobile website, a dynamic serving website, or a responsive website (15). These configurations are described, analysed, and compared below. As with the desktop design, screen resolution must also be analysed.

2.2.2.1 Separate mobile and desktop websites

The first configuration is to have separate URLs for the mobile and desktop websites. Mobile devices are redirected to the mobile page from the desktop page based on the size of their screen. This is useful for changing the browsing experience of mobile users. For example, a large social media site might have a separate mobile site with much smaller pictures and reduced content in order to reduce loading times

One disadvantage is that there are two versions of the website to maintain. A second is that, due to their large screen size, tablets are generally directed to the desktop version of the website. This means users of tablets on a mobile network may suffer high data usage and slow loading times. A third disadvantage for this method is that redirecting can be prone to mistakes and is detrimental to load times.

2.2.2.2 Dynamic serving website

The second configuration is to create a dynamic serving website. This allows mobile and desktop websites to share the same URL but still have different HTML and CSS and thus different content. It also allows the page to be optimised multiple mobile devices. For example, there could be one version for tablets and another for smartphones. This configuration removes some of the complexity of redirecting at the cost of more complex HTML.

Another disadvantage is that this configuration relies on the server using user agents to identify the device trying to access the page; this means that the list of user agents needs to be updated as soon as a new mobile device is released so that the website doesn't become outdated.

2.2.2.3 Responsive website

A responsive website means that all devices use the same URL and HTML. CSS is used to render the page depending on the width of the screen being used. One advantage of this is that the site works well with a wide and continuous range of screen sizes. The style of the

page changes to accommodate the changing width at set break points. For example, when a screen is too small the display the entire width of a line of section links, the links may compress into a grid or even a single button. Between these break points the page fluidly scales with changes in the width of the screen. A second advantage is that it is easier to maintain only one version of the website.

Google recommends using a responsive web design (16), as it makes it easier for Google's crawlers to index the page.

A disadvantage is that the content is the same for both the desktop and the mobile website. Therefore it is imperative that the desktop website is light so that the mobile website can load quickly – this could be restrictive to the content of the desktop site.

2.2.2.4 Comparison and conclusions

Table 2.2 The key features of different mobile design configurations (17)

Characteristic	Separate websites	Dynamic Serving	Responsive website
Allows separate content for desktop and mobile users	✓	✓	x
Allows page to be displayed differently for range of mobile devices	x	✓	✓
Allows for a continuous range of device width	x	x	✓
Easy to maintain	x	x	✓
Easy for search engines to index	x	x	✓

Table 2.2 shows that for the patient website it is best to use a responsive design. The desktop website has been designed to be simple and concise, meaning it is not necessary to

reduce the content so the page is suitable for viewing on a mobile device. As a result, the patient website can make use of the advantages of a responsive website. The comparatively low maintenance requirement is particularly important in the healthcare industry, as reduced maintenance costs mean more money can be spent on other important medical services.

2.2.2.5 Minimum screen resolution

Figure 2.11 shows the mobile screen resolution for the UK over the past 6 months. The graph is very volatile and it is difficult to induce trends. The main takeaway from this data is that almost no mobile screens are smaller than 320 pixels in width. In March 2014, only 0.3% of users had 240x320 screens. There is also 5.1% 'unknown' and 16.7% 'other'. If we assume that the same proportion of users within these two categories are using similarly small screens compared to the remaining 78.2% of the population, we arrive at the conclusion that approximately 0.4% of the whole UK population will be using screens with a width smaller than 320 pixels. This is negligible so the minimum design width will be 320 pixels.

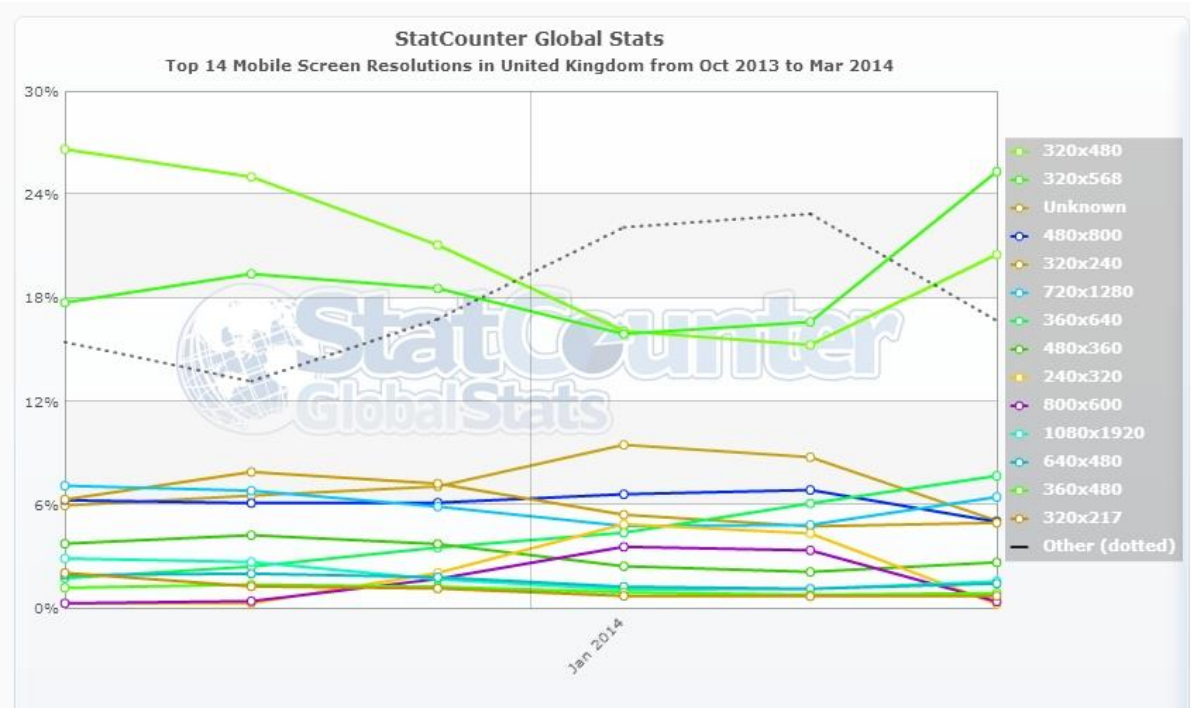


Figure 2.11 Graph of mobile screen resolution in the UK for the past 6 months (12)

2.2.2.6 CSS pixels vs hardware pixels

Pixels are discussed throughout this section of the report. All pixels mentioned are CSS pixels, but it is important to distinguish between CSS pixels and hardware pixels (18). When establishing the width of a mobile screen it will query the 'device-width'. An iPhone 3 with a hardware width of 320 pixels has a device-width of 320 pixels. An iPhone 4 has a hardware width of 640 pixels but a device-width of 320 pixels (19). This is because although the iPhone 4 has a high screen resolution, the screen is the same size as the iPhone 3: if it had a device-width of 640 pixels then website content would be half the size and unreadable. By setting the iPhone 4 device-width to 320 pixels, website content will look the same on the iPhone 4 as it does on the iPhone 3. Therefore, for the iPhone 4, one CSS pixel is made up of a square of 4 hardware pixels. Device-width is set by smartphone manufacturers to make sure their produce displays mobile web pages correctly. This means it is possible to design a website using CSS pixels without worrying about the hardware resolution.

2.2.3 Mobile website design

The mobile website can now be designed based on the considerations discussed. The design of the desktop website suggests three breakpoints are necessary in order to scale the content for use on a smartphone.

2.2.3.1 Breakpoint 1

The first breakpoint happens at 920 pixels. This is when the width of the screen is equal to the width of the content as defined in section 2.1.4.1 on page 29. At this point, the subsection menu on each page disappears and the picture and body text expand to the width of the screen in order to turn the page into a single scrollable column. The two exceptions are the home page, which has no subsection menu and so is already in single-column format, and the information form, which remains in two-column format until breakpoint 2. On the home page, the transparent grey caption bar for the picture becomes opaque – this is so that the picture behind it can scale whilst maintaining its aspect ratio and

so that the caption text can stay legible. The pages then condense horizontally until breakpoint 2.

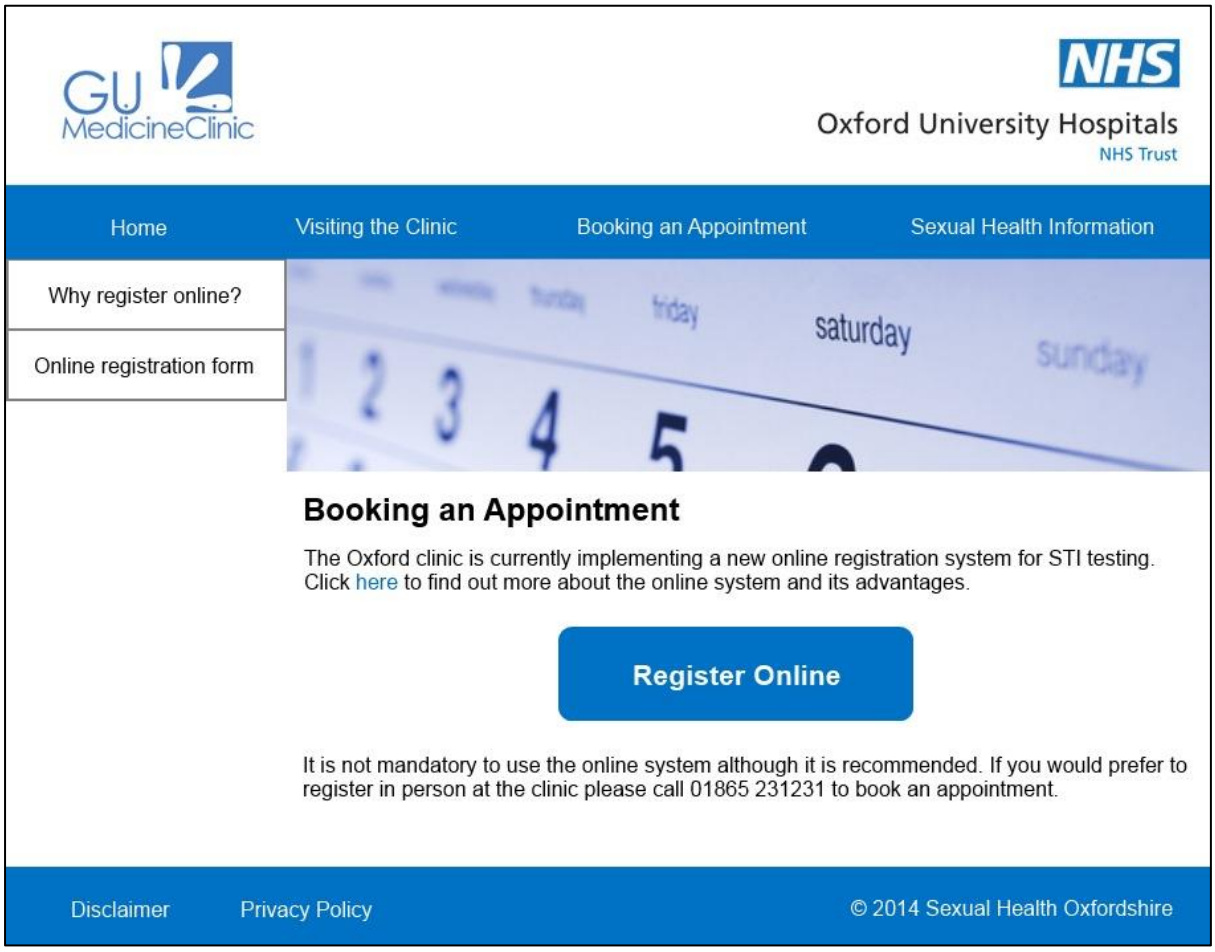


Figure 2.12 The Booking an Appointment page just before breakpoint 1

Figure 2.12 and Figure 2.13 show the differences before and after the breakpoint. As can be seen in Figure 2.13, the example picture (20) and body content have expanded to fit the width of the screen and the header and footer logos and links have moved closer together. Only the picture changes size as the page scales – the text, the 'register online' button and the logos stay the same size. This means that space between the logos will decrease, as will the space between the 'register online' button and the edge of the screen. As text size is staying the same, paragraph height will increase as width decreases. Space between the links in the header and footer will decrease.

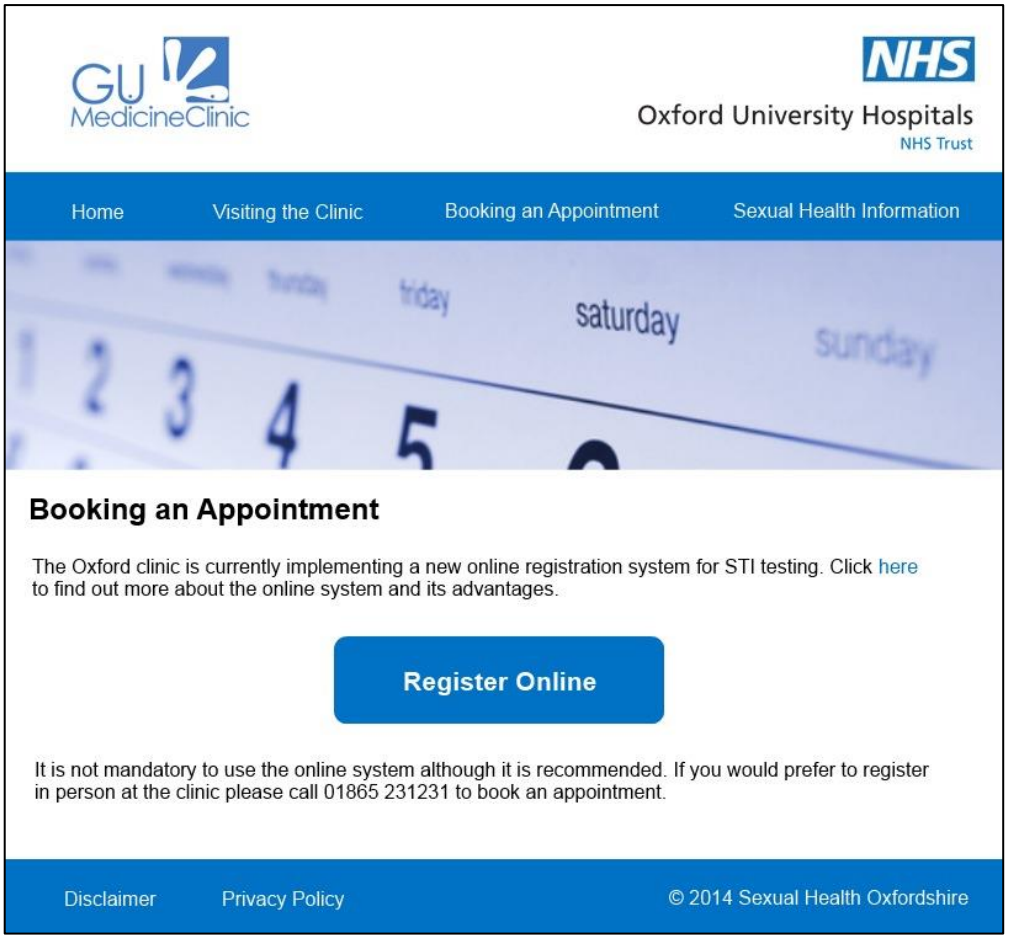


Figure 2.13 The Booking an Appointment page between breakpoints 1 and 2

2.2.3.2 Breakpoint 2

The second breakpoint happens at 690 pixels, when the links in the header are unable to move any closer together. At this point the links in the header contract into a single menu button. The menu button design is three horizontal bars with an outline to make it obvious that it is a button.

Figure 2.14 shows the change to the header links after breakpoint 2. When the menu button is clicked, as multi-layer toggle menu expands between the header banner and the picture. This menu initially lists all the sections and when a section is clicked, a list of the related subsections expands. The section links are blue with white text. To keep formatting consistent with the side menu on the desktop page, the subsection links are white with black text and the sub-subsection links are grey with white text. This is illustrated in Figure 2.17.

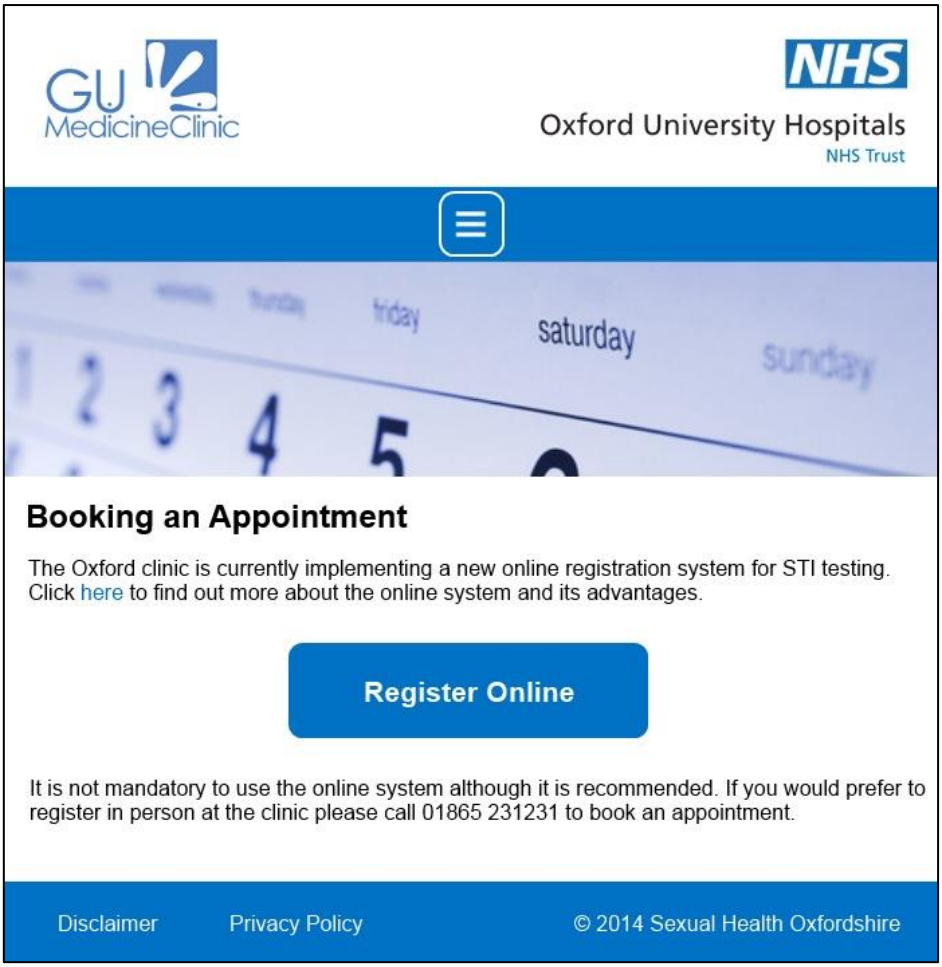


Figure 2.14 The Booking an Appointment page immediately after breakpoint 2

The information form page has an additional change at this breakpoint: the form changes from a two-column layout as shown in Figure 2.7 to a single-column layout as shown in Figure 2.18. Section 2.2.3.5 explains adapting online forms for mobile use in detail.

2.2.3.3 Breakpoint 3

The third break point happens at 500 pixels. This is when both the logos and the footer text cannot move any closer together. At this point the footer doubles in thickness, with the copyright text moving below the 'disclaimer' and 'privacy policy' links as shown in Figure 2.15. Between this point and the minimum width, the logos decrease in size whilst maintaining their aspect ratio. The rest of the content scales as before; the picture scales and maintains its aspect ratio, text stays the same size, and empty space is reduced.

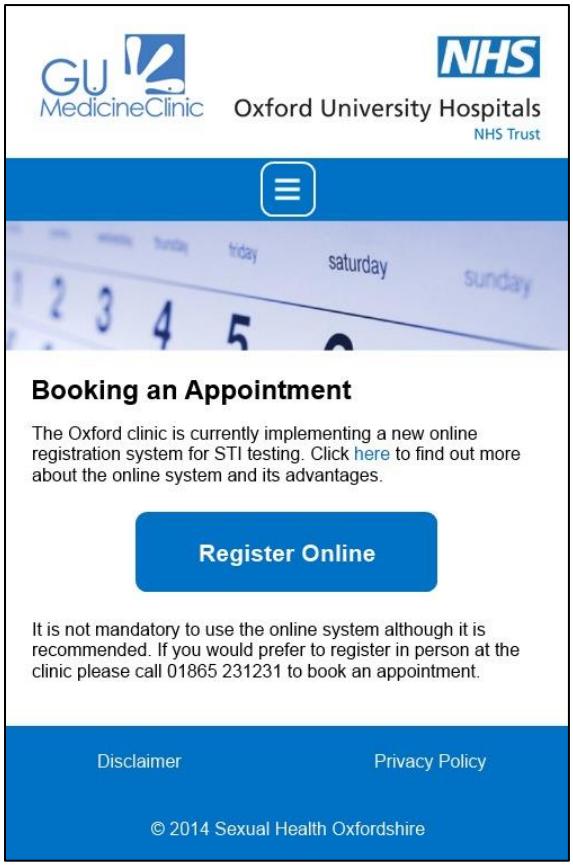


Figure 2.15 The Booking an Appointment page immediately after breakpoint 3

2.2.3.4 Minimum width

The minimum width is 320 pixels as defined in section 2.2.2.5 on page 41. Figure 2.16 shows how the page will look on a 320x480 smartphone. It is possible to scroll through all content on the page, all text is readable, and all buttons are a suitable size for use with touch screens (21). Figure 2.17 shows the expansion of the menu as the user clicks on 'Sexual Health Information' and then 'STIs'. It is necessary to scroll through the menu as it expands in order to prevent the links becoming too small.

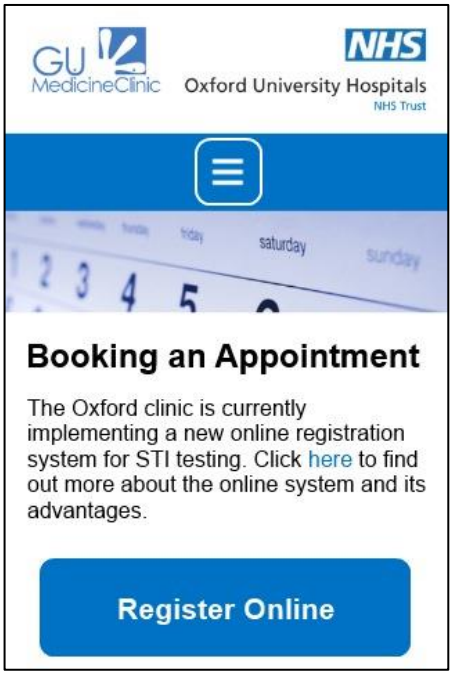


Figure 2.16 The Booking an Appointment page at minimum width

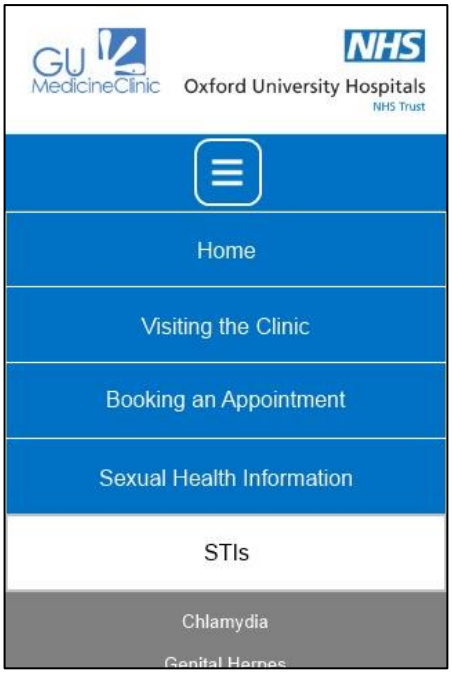


Figure 2.17 View from a smartphone when the STI subsection is selected from the menu

2.2.3.5 Information form design

It is important to consider the different types of field within the form and how well these field types might work with mobile devices. Check-boxes and radial select buttons work well with mobile devices, especially touch screens. Drop-down select menus could prove a problem if they operate in the same way on mobile devices as desktop devices, as a long list could easily be larger than the size of the screen. However mobile device manufacurers have considered this when designing their devices (22). Android, iOS, and Windows Phone all have a user-friendly interface for drop-down select menus.

Thus for the form, as with the rest of the website, the issue is formatting rather than a complex re-design of fields. Figure 2.7 shows that on the desktop version of the website, field labels are on the left and the related field is aligned right. As the screen width is reduced it is necessary to re-format the form so that the field labels are top aligned with the field. This puts the content into a single scrollable column and means that the user can always see the label for the field they are using. This is shown in Figure 2.18.

Figure 2.18 Information form as viewed from a smartphone

2.3 Conclusion

The patient website has been designed with two functions. The primary function is to allow patients to fill in information on their sexual history and their registration details. This information is then submitted to the database. The secondary function is to offer information about the clinic and about sexual health in general.

The design of the website is modern whilst still complying with the NHS branding guidelines. The responsive nature of the website means it will be easier to maintain in the future for two reasons. Firstly, because it has been designed to display well through a continuous range of screen sizes from 320 pixels upwards, it will not need to be updated whenever new mobile devices with different screen widths are released. Secondly, because there is only one version of the HTML and CSS, the time to update the website and the likelihood of error is reduced.

The result is a website which fulfils its required functionality, looks good, and is as future-proof as possible.

3 Doctor Application

This section aims to present how the clinical guidelines for diagnosing and treating sexually transmitted infections are implemented to form the doctor application. The purpose of this application is to provide decision support for the medical professional throughout the process of diagnosis and treatment of sexually transmitted infections. This has been done using the software tool Tallis to create a PROForma application that can run in a web browser. Tallis has been used because this is a software tool specifically designed to create applications for medical analysis. Decision making properties in particular make a Tallis application appropriate for this type of system. In addition, Tallis is designed to make the creation of applications incorporating decision support and workflow simple.

3.1 Tallis and PROForma

The software used in developing the doctor part of the app is a tool called Tallis that produces a program in the language PROForma. PROForma is a Task Network Language for programming decision support and workflow (23). It uses a set of different tasks called actions, decisions, enquiries and plans which can be seen in Figure 3.1.

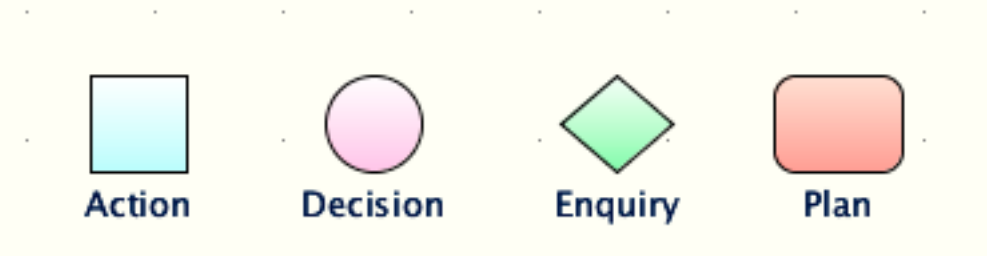


Figure 3.1 Tasks in Tallis

There are specific properties of each task and there are also some properties common to all tasks. An action is a simple activity that interacts with the environment outside the app. For example, an action could display a message to a medical professional on the screen. A decision is an activity where a choice is made between a number of alternatives. This is done by presenting arguments for and against each alternative and allowing the user to confirm

the decision to be made. This is a feature that makes PROForma particularly suitable for medical applications as the medical professional makes the decision using supporting arguments presented by the program. An example of a decision task can be seen in Figure 3.2.

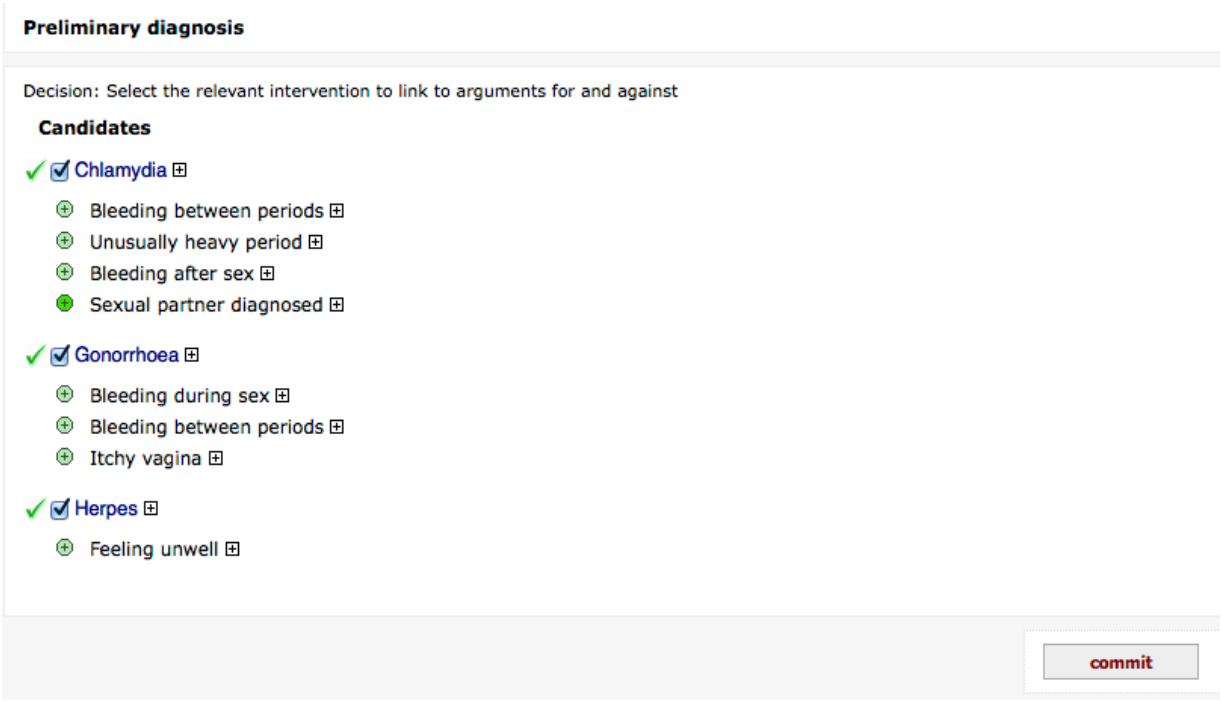


Figure 3.2 Example of decision

An enquiry is a task that acquires information. This can be done by directly asking the user to input data or it could also get information by for example requesting the data from a database. Finally, a plan is a method of collecting a number of other tasks into a subset of tasks, which helps create a simple overview of the application (24).

3.2 Overview of application

The purpose of the doctor app is to present the patient responses to the doctor or medical professional in a way that supports decision-making on diagnosis and treatment. This is achieved through a Tallis app that retrieves the patient answers from the database and then runs the process for diagnosis and treatment. A simple overview of this application can be seen in Figure 3.3.

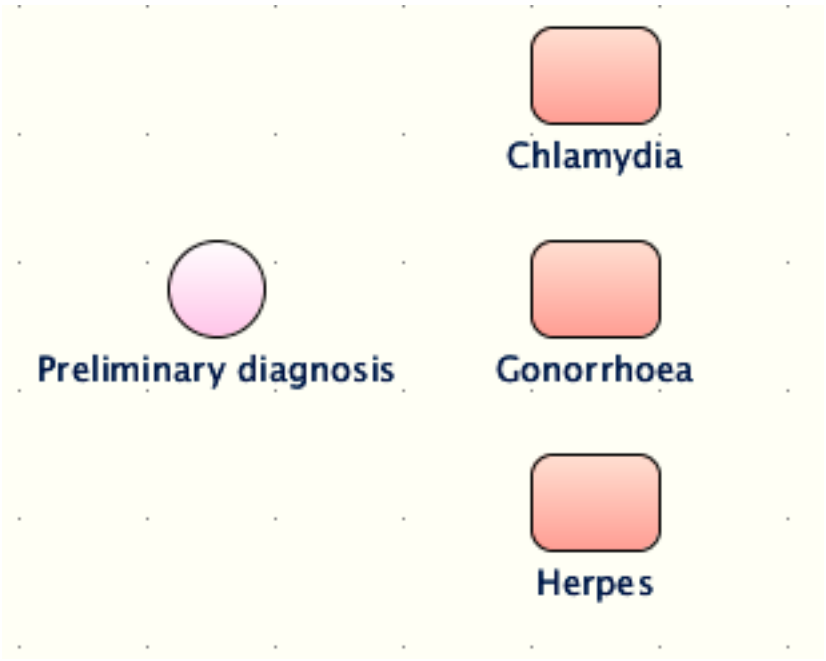


Figure 3.3 Overview of doctor application

The preliminary diagnosis is a decision that takes into account all the symptoms that the patient has experienced, the patient's sexual history sexual history and any other factors that would put the patient at risk for particular infections in order to determine which sexually transmitted diseases the patient might be infected by. This preliminary diagnosis can be used by the doctor in deciding what tests to perform. Once the doctor has confirmed one or more tests to be performed the application moves on to the relevant treatment plans for all the chosen diseases. The order of execution of the tasks is controlled using preconditions and state triggers. The precondition of a task is a statement which has to be true before the task

can be performed (25). A state trigger is an expression which while it is false the task remains dormant and when it becomes true the task is executed. If at this point the precondition is not met, the task will be discarded (25). The treatment plans for the diseases are controlled only through a state trigger. The trigger is based on the outcome of the diagnosis decision and the expression used for chlamydia is, as can be seen from Figure 3.4, "*result_set(Preliminary_Diagnosis) includes "Chlamydia"* ". The other diseases use the same expression with chlamydia substituted for the relevant disease. This expression will be true when the relevant disease is a confirmed result of the diagnosis decision.

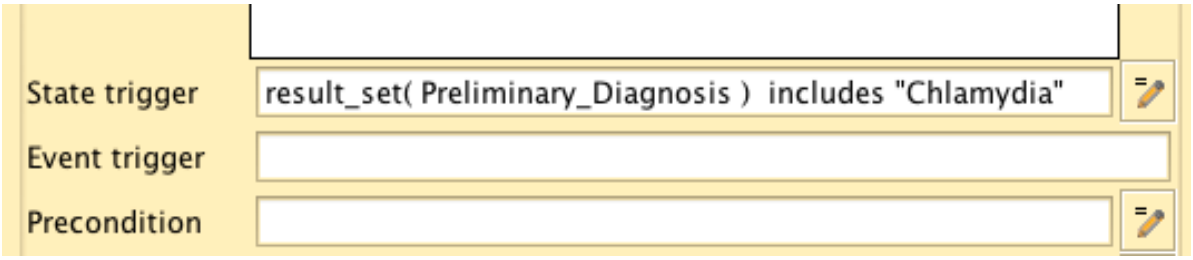


Figure 3.4 Use of State trigger to control workflow

The reason for using only state triggers and not including any preconditions is to avoid discarding any tests even if they are not confirmed. In the current version of the application this is symbolic since it does not affect the execution of the application. However, future versions of the application could perhaps include features such as returning to the diagnosis stage if tests are negative or if new symptoms arise. For each disease there is a treatment plan that guides the medical professional through the testing and if tests return positive, recommends how to treat the disease.

3.3 Preliminary diagnosis

The preliminary diagnosis decision includes arguments for each of the sexually transmitted infections. Chlamydia, Gonorrhoea and Herpes are all candidates, or potential results, of the decision. The arguments include all the relevant symptoms, whether a previous sexual partner has been diagnosed with the disease and if the patient just wants a general check-up. For example, chlamydia has 13 arguments. This includes 11 male and female symptoms, a previous sexual partner diagnosed with chlamydia and a patient wanting a general check-up.

The relevant symptoms of each infection come from the Medical background research in section1. All symptoms are split into the categories male and female symptom. This is because the list of possible symptoms is different for male and female patients. Some symptoms can be experienced by both male and female patients and these are repeated in both lists. The reason for using two separate lists rather than one list including both the male and female symptoms is that this way an enquiry can be produced in the patient interface where the patient can select symptoms from a list of only relevant symptoms if they are male or female. This contributes to making the patient part of the application more user friendly.

As can be seen from Figure 3.5, which shows a list of all the arguments relating to chlamydia, each argument that is a symptom has a (+) next to it. This means that it is an argument for the particular candidate, as opposed to an argument against it. The argument of a sexual partner diagnosed with the STI carry the support (++) meaning a conclusive argument. This is because if a previous partner has been diagnosed then the patient should definitely get tested. It is also worth noting that there are no arguments against any of the tests. This is because as long as there is any reason to perform a test then this should be done.

Argument list

```
Chlamydia_Arg_01 {femaleSymptoms  includes "Pain when peeing"     } (+ )
Chlamydia_Arg_02 {femaleSymptoms  includes "Different vaginal discharge"     } (+ )
Chlamydia_Arg_03 {femaleSymptoms  includes "Pain in the lower abdomen"    } (+ )
Chlamydia_Arg_05 {femaleSymptoms  includes "Pain during sex"    } (+ )
Chlamydia_Arg_06 {femaleSymptoms  includes "Bleeding after sex"     } (+ )
Chlamydia_Arg_07 {femaleSymptoms  includes "Bleeding between periods"     } (+ )
Chlamydia_Arg_08 {femaleSymptoms  includes "Heavier period than usual"    } (+ )
Chlamydia_Arg_09 {maleSymptoms  includes "Pain when peeing"    } (+ )
Chlamydia_Arg_10 {maleSymptoms  includes "Discharge from the penis tip"     } (+ )
Chlamydia_Arg_11 {maleSymptoms  includes " Pain in the testicles"    } (+ )
Chlamydia_Arg_12 {PartnerSTI  includes "Chlamydia" } (++)
Chlamydia_Arg_13 {Reason  = "General checkup"} (+ )
```

Figure 3.5 Chlamydia argument list

An expanded view of the first argument on the list can be seen in Figure 3.6. This includes the condition that must be true for the argument to be valid. If this condition is not satisfied the argument will not appear when running the decision. There is also a caption and a description. The caption is how the argument is presented when running the decision and when the doctor requests more information about a particular argument by pressing a button the full description shows up. This description could also include features such as a link to a reference where the doctor could find out even more. An example of what this decision could look like when it is running can be seen in Figure 3.2 in section **Error! Reference source not found.**

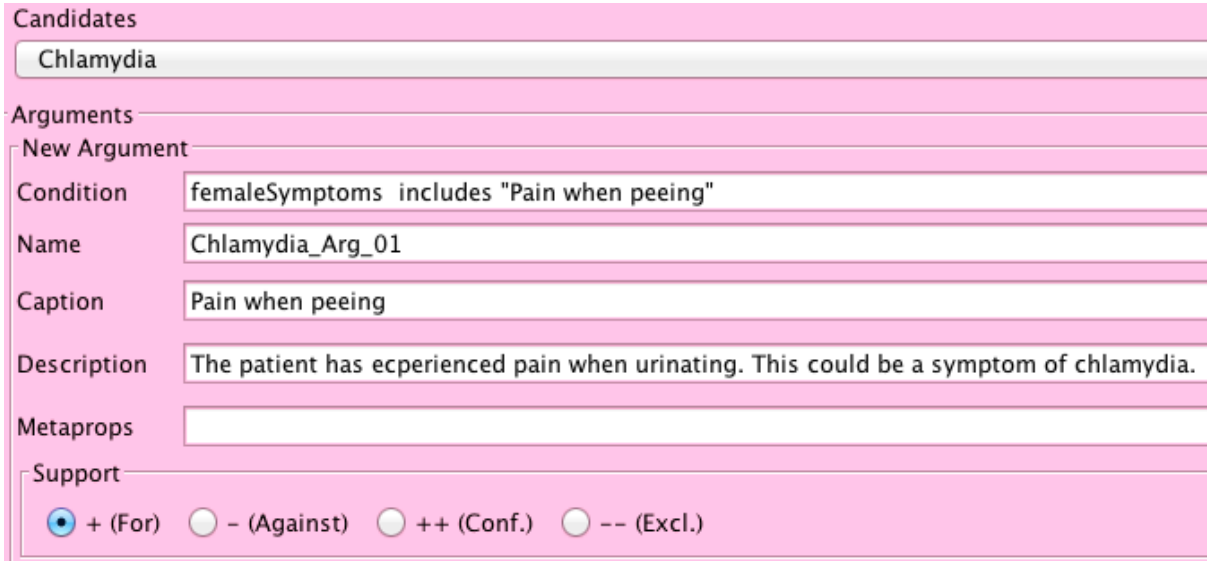


Figure 3.6 Detailed view of chlamydia argument "Pain when peeing"

Furthermore, the other diseases have similar argument lists to that of chlamydia, which include all relevant symptoms, partners diagnosed with the disease and whether the patient wants a general check-up. The arguments for gonorrhoea can be seen in Figure 3.7and the list of herpes arguments in Figure 3.8.

```
Gonorrhoea_Arg_01 {maleSymptoms includes "Itching penis tip" } (+ )
Gonorrhoea_Arg_02 {maleSymptoms includes "Pain when peeing" } (+ )
Gonorrhoea_Arg_03 {maleSymptoms includes "Pain in the testicles" } (+ )
Gonorrhoea_Arg_04 {maleSymptoms includes "Peeing more frequently than usual" } (+ )
Gonorrhoea_Arg_05 {maleSymptoms includes "Rectal pain" } (+ )
Gonorrhoea_Arg_06 {maleSymptoms includes "Swollen testicles" } (+ )
Gonorrhoea_Arg_07 {maleSymptoms includes "Thick penis discharge" } (+ )
Gonorrhoea_Arg_08 {femaleSymptoms includes "Pain in the lower abdomen" } (+ )
Gonorrhoea_Arg_09 {femaleSymptoms includes "Bleeding during sex" } (+ )
Gonorrhoea_Arg_10 {femaleSymptoms includes "Bleeding between periods" } (+ )
Gonorrhoea_Arg_11 {femaleSymptoms includes "Different vaginal discharge" } (+ )
Gonorrhoea_Arg_12 {femaleSymptoms includes "Increased vaginal discharge" } (+ )
Gonorrhoea_Arg_13 {femaleSymptoms includes "Itchy vagina" } (+ )
Gonorrhoea_Arg_14 {femaleSymptoms includes "Pain when peeing" } (+ )
Gonorrhoea_Arg_15 {femaleSymptoms includes "Pain during sex" } (+ )
Gonorrhoea_Arg_16 {femaleSymptoms includes "Red vagina" } (+ )
Gonorrhoea_Arg_17 {femaleSymptoms includes "Swollen vagina" } (+ )
Gonorrhoea_Arg_18 {PartnerSTI includes "Gonorrhoea" } (++)
Gonorrhoea_Arg_19 {Reason = "General checkup" } (+ )
```

Figure 3.7 Gonorrhoea argument list

```
Herpes_Arg_01 {femaleSymptoms  includes "Blisters in the genital area"       } (+ )
Herpes_Arg_02 {femaleSymptoms  includes "Blisters on the cervix (lower part of the womb)"       } (+ )
Herpes_Arg_03 {femaleSymptoms  includes "Different vaginal discharge"       } (+ )
Herpes_Arg_04 {femaleSymptoms  includes "Pain when peeing"       } (+ )
Herpes_Arg_05 {femaleSymptoms  includes "High temperature"       } (+ )
Herpes_Arg_06 {femaleSymptoms  includes "Feeling generally unwell"       } (+ )
Herpes_Arg_07 {femaleSymptoms  includes "Burning or tingling sensation around genital area"       } (+ )
Herpes_Arg_08 {maleSymptoms  includes "Blisters in the genital area"       } (+ )
Herpes_Arg_09 {maleSymptoms  includes "Pain when peeing"       } (+ )
Herpes_Arg_10 {maleSymptoms  includes "High temperature"       } (+ )
Herpes_Arg_11 {maleSymptoms  includes "Feeling generally unwell"       } (+ )
Herpes_Arg_12 {maleSymptoms  includes "Burning or tingling sensation around the genital area"       } (+ )
Herpes_Arg_13 {PartnerSTI  includes "Herpes"  } (++)
Herpes_Arg_14 {Reason  = "General checkup" } (+ )
```

Figure 3.8 Herpes argument list

The outcome of the decision is based on the arguments whose conditions are true. If there are one or more relevant arguments for a disease then a test for this disease will be recommended. This can be seen in Figure 3.9 where the decision rule is based on the net support being greater than or equal to 1. Net support is the sum of all the supports where an argument for a candidate with the support (+) counts as 1. As a result, a net support greater than or equal to 1 when there are no arguments against a candidate means that the candidate will be recommended as long as there is at least one argument for. In addition, if there are arguments for several tests to be performed they will all be recommended. The order that the recommendations are presented is based on the net support. The disease with the highest net support will be on top of the list. If the net support is the same for more than one disease chlamydia will be on top, followed by herpes. This is because chlamydia is the most common sexually transmitted disease followed by herpes (26).

Figure 3.9 Chlamydia decision rules

The decision allows for multiple selections, meaning that several alternatives can all be chosen. This is because if the patient is at risk for several sexually transmitted infections all relevant tests should be performed to be safe rather than just choosing one test.

3.4 Treatment plans

As seen in Figure 3.3 in the section Overview of application each sexually transmitted infection has a plan to represent the pathway of diagnosing and treating that particular disease. These are different depending on the disease but they all follow clinical recommendations, as found in section 1, and guide the medical professional throughout the process from testing for the disease to prescribing the most suitable treatment for the individual patient needs.

3.4.1 Chlamydia

The structures of the treatment plans are similar for all the infections but there are also significant differences in how to treat each disease. The testing and treatment of chlamydia follows the process seen in **Figure 3.10**.

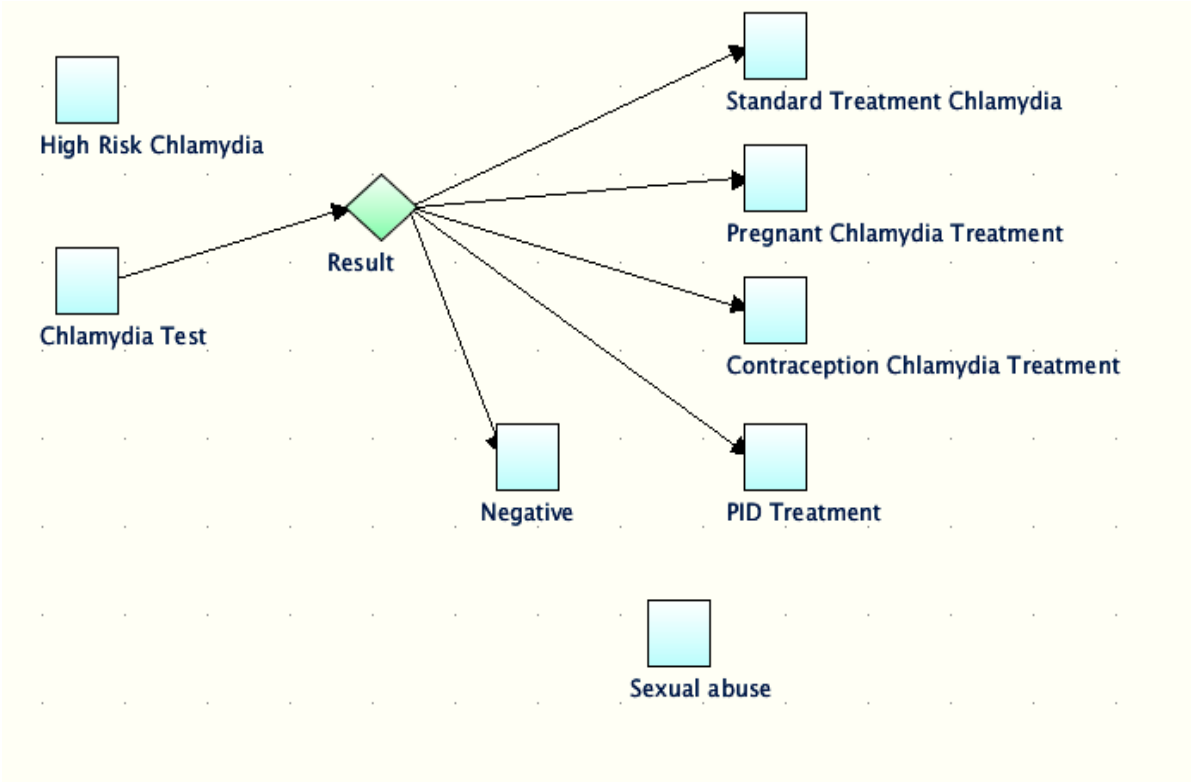


Figure 3.10 Chlamydia treatment plan

The first stage is Chlamydia Test. This is an action telling the medical professional to perform the urine sample or vaginal swab test in order to diagnose whether the patient has chlamydia. Once this is confirmed, an enquiry asks the user to input the result of the test which will be positive or negative. If the result is negative an action appears asking the medical professional to “inform patient that test result was negative” and to “consider if there is reason to test for other STIs”. However, if the test results are positive the following action depends on some of the patient information. For a male patient or a female patient who is not pregnant, breastfeeding, on contraception or suffering from a pelvic inflammatory disease, standard treatment will be recommended, which is represented by the action Standard Chlamydia Treatment. This action will display a message on the screen such as the one seen in **Figure 3.11** telling the user to prescribe an antibiotic that suits the patient needs. The action also reminds the professional to “advise the patient to not have sex for at least a week after the end of treatment and not until all symptoms have stopped” and to “contact previous sexual partners”.

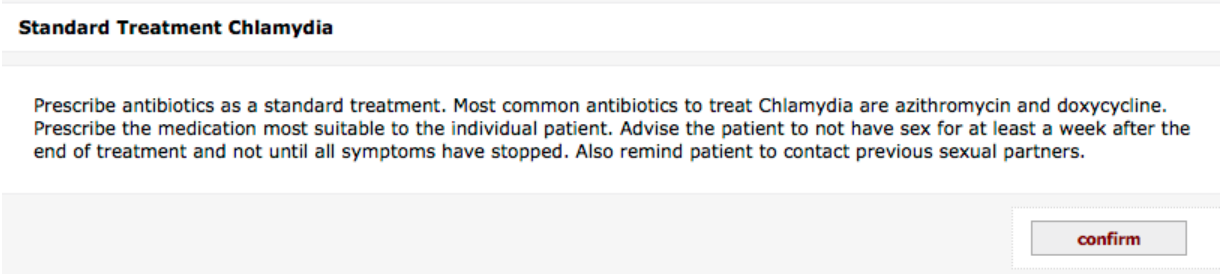


Figure 3.11 Chlamydia standard treatment advice

The actions for patients with special conditions are similar but also give advice relevant to the particular condition. For example, if a patient is pregnant or breastfeeding the action "Pregnant Chlamydia Treatment" will run. In addition to the general guidelines for a patient with chlamydia this reminds the professional to prescribe antibiotics that are safe for pregnant or breastfeeding women such as azithromycin, amoxicillin and erythromycin (27). Furthermore, if a patient is on contraception the action also points out that most antibiotics will not interfere with contraception but to watch out for medication causing vomiting or diarrhoea as this could reduce the effectiveness of oral contraception pills (27). Finally, if a patient suffers from a pelvic inflammatory disease (PID) the treatment of chlamydia differs from the standard treatment. If this is the case the action "PID treatment" will appear advising the doctor to follow treatment guidelines for pelvic inflammatory disease.

In addition to the regular workflow, the chlamydia treatment plan also contains two flag actions. The first of these is "High Risk Chlamydia" which appears automatically if a patient is at high risk due to a sexual partner being diagnosed with chlamydia. In this case the medical professional should consider starting treatment for chlamydia before test results are ready. This action will, if relevant, appear before the action requesting test to be performed. The second flag action is "Sexual abuse" which appears if a patient under the age of 18 is tested positive for chlamydia. This reminds the medical professional to also consider sexual abuse.

The timing within this workflow is controlled using preconditions and state triggers. The first task to appear if relevant is the "High Risk Chlamydia" action. This is triggered as soon as the Chlamydia plan is entered and uses the precondition "*PartnerSTI includes "Chlamydia*"".

Following this, the test action is activated using the sate trigger *"is_completed(High_Risk_Chlamydia) OR is_discarded(High_Risk_Chlamydia)*". If the result is negative the action "Negative" is triggered through the state trigger "*ChlamydiaResult = "Negative"* ". The different treatment options in case of positive test result all have the state trigger "*ChlamydiaResult = "Positive"* " but different preconditions such that they will be triggered if the condition is true and discarded otherwise. For example, the precondition for "Standard Treatment" is as can be seen in Figure 3.12 "*gender = "Male" OR FemaleConditions = "No other conditions"* ".

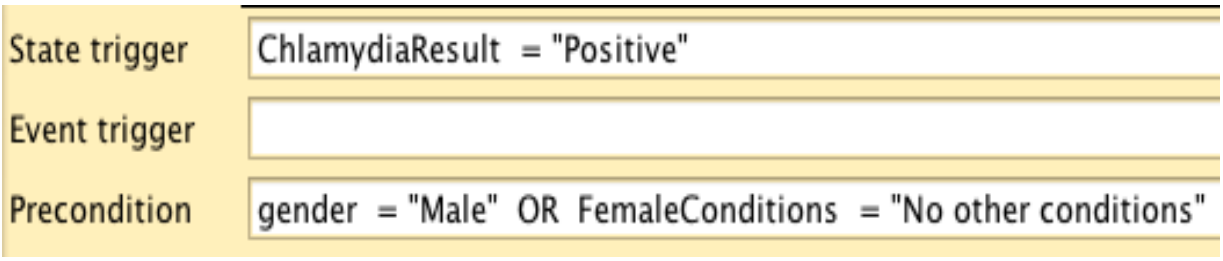


Figure 3.12 Use of state trigger and precondition to control workflow

The other treatments use similar preconditions such as "*FemaleConditions = "Breastfeeding" OR FemaleConditions = "Pregnant"* " for the action "Pregnant Chlamydia Treatment", which will be true for any patient who is pregnant or breastfeeding, "*FemaleConditions = "On contraception"* " for the action "Contraception Chlamydia Treatment" and "*FemaleConditions = "Suffering from a PID"* " for the action "PID Treatment". Lastly, the action "Sexual Abuse" uses the precondition "*Age < 18 AND ChlamydiaResult = "Positive"* " and can therefore activate when a patient under 18 tests positive for chlamydia.

3.4.2 Gonorrhoea

The treatment plan for gonorrhoea is relatively simple compared to the other diseases. This treatment plan can be seen in Figure 3.13.

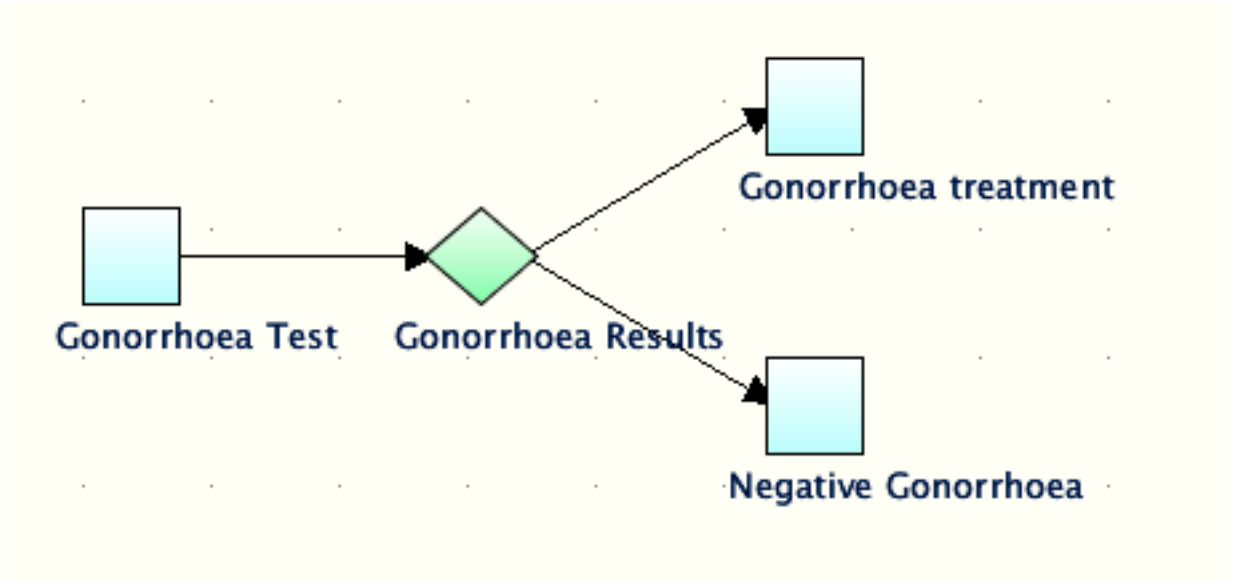


Figure 3.13 Gonorrhoea treatment plan

The plan simply consists of an action “Gonorrhoea Test” advocating Gonorrhoea test to be performed. The doctor or medical professional later inputs the test result using the enquiry “Gonorrhoea Results”. If the patient is tested negative the action “Negative Gonorrhoea” will appear and advise the medical professional to inform patient of the results and consider testing for other diseases. On the other hand, if the test is positive the action “Gonorrhoea treatment” is activated and tells the medical professional to “as standard treatment, prescribe Ceftriaxone 500 mg intramuscularly as a single dose with azithromycin 1 g oral as a single dose” but also emphasises that the individual patient situation should be taken into account when prescribing drugs. The action also reminds the medical professional to ask the patient to contact previous sexual partners and tell them to get tested.

Similarly to other parts of the application, state triggers are used to control the timing of the tasks. The enquiry about results uses the trigger “*is_completed(GonorrhoeaTestAction)*” which is true as soon as the test action is confirmed by the user. The treatment and negative test actions are triggered using state triggers based on the test results. The trigger for the treatment is “*gonorrhoeaTestResult = “Positive”* " and the same expression is used for the negative test action with “Negative” instead of “Positive”.

3.4.3 Herpes

The testing and treatment of herpes is slightly different since if the patient has no blisters or sores in the genital area no test can be performed. The pathway for test and treatment of genital herpes can be seen in Figure 3.14.

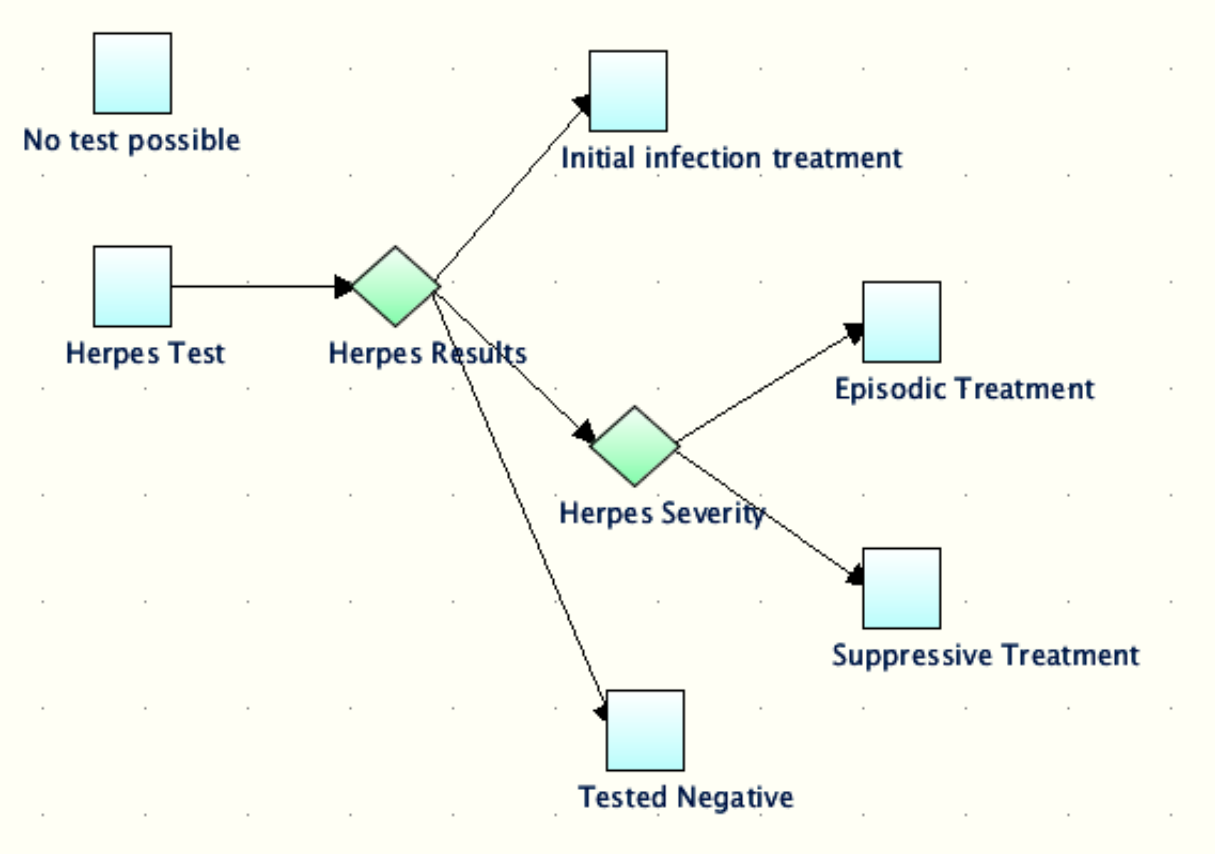


Figure 3.14 Herpes treatment plan

The test for herpes cannot be performed unless the patient has blisters or sores around the genital area. This is because the test is done by taking a swab from the sore for analysis (28). Therefore, the treatment plan for herpes starts with the action “No test possible” which is activated if the patient has not indicated that they are suffering from blisters. This is done using the precondition “*not((femaleSymptoms includes "Blisters in the genital area") OR (maleSymptoms includes "Blisters in the genital area”))”.* This action shows a message to the medical professional informing that no test can be perform but also pointing out that the

patient could still be suffering from genital herpes and to consider treating for the disease depending on other symptoms.

On the other hand, if the patient is suffering from blisters and a test can be performed the action “No test possible” will be discarded, which triggers the action “Herpes Test”. This action uses the state trigger “*is_discarded(NoHerpesTestAction)*” and tells the medical professional to take a swab sample and to ask some relevant questions about symptom frequency and severity. Once this action has been confirmed the enquiry “Herpes Results” is activated. This allows the doctor to input test results and also answer whether the patient has experienced similar symptoms previously as seen in Figure 3.15.

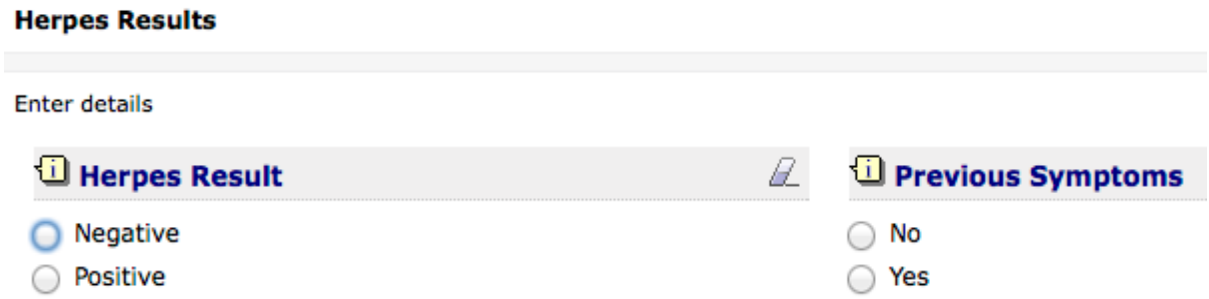
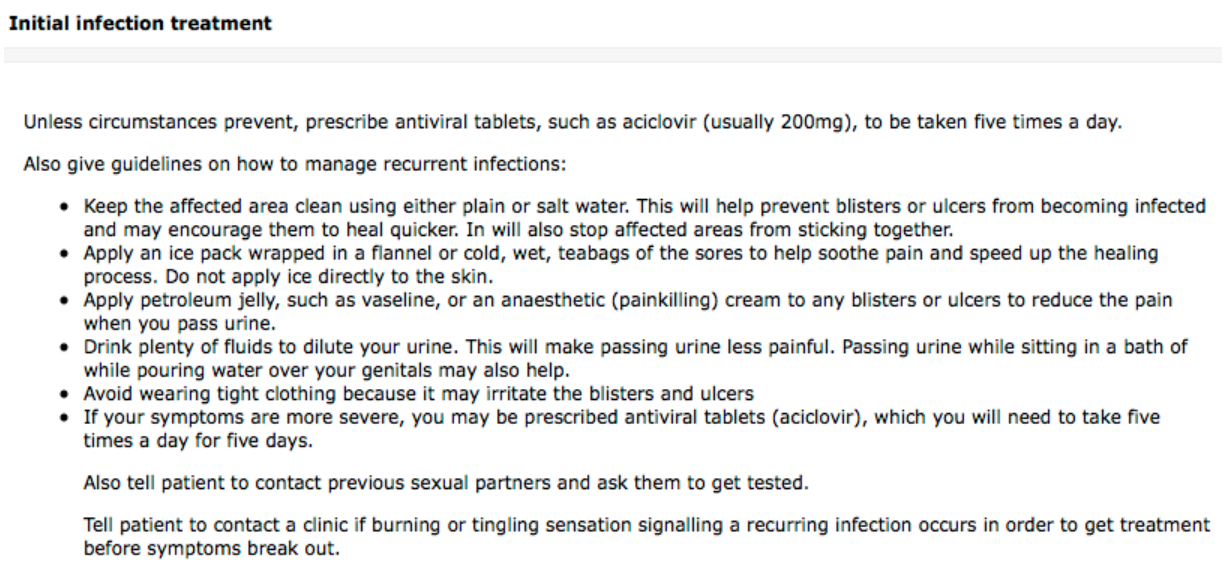


Figure 3.15 Enquiry about herpes test results and symptom history

The following task depends on the information from the enquiry. If the patient is tested negative the action “Tested Negative” is activated. This tells the doctor to inform the patient of the negative test result but to keep in mind that the test is not conclusive and therefore tell the patient to return if further symptoms are experienced (29). However, if the test results are positive and the patient has not experienced any previous symptoms, the action “Initial Infection treatment” starts which is a message to the doctor to “unless circumstances prevent, prescribe antiviral tablets, such as aciclovir (usually 200mg), to be taken five times a day” as the standard treatment for initial herpes infection (30). The message also contains plenty of advice for the doctor to give the patient about maintenance of a herpes infection and how to deal with outbreaks in the future as seen in Figure 3.16. Finally, the action

reminds the doctor to tell the patient to contact previous sexual partners and ask them to get tested.



Initial infection treatment

Unless circumstances prevent, prescribe antiviral tablets, such as aciclovir (usually 200mg), to be taken five times a day.

Also give guidelines on how to manage recurrent infections:

- Keep the affected area clean using either plain or salt water. This will help prevent blisters or ulcers from becoming infected and may encourage them to heal quicker. In will also stop affected areas from sticking together.
- Apply an ice pack wrapped in a flannel or cold, wet, teabags of the sores to help soothe pain and speed up the healing process. Do not apply ice directly to the skin.
- Apply petroleum jelly, such as vaseline, or an anaesthetic (painkilling) cream to any blisters or ulcers to reduce the pain when you pass urine.
- Drink plenty of fluids to dilute your urine. This will make passing urine less painful. Passing urine while sitting in a bath of while pouring water over your genitals may also help.
- Avoid wearing tight clothing because it may irritate the blisters and ulcers
- If your symptoms are more severe, you may be prescribed antiviral tablets (aciclovir), which you will need to take five times a day for five days.

Also tell patient to contact previous sexual partners and ask them to get tested.

Tell patient to contact a clinic if burning or tingling sensation signalling a recurring infection occurs in order to get treatment before symptoms break out.

Figure 3.16 Treatment advice for initial herpes infection

Furthermore, if the patient has experienced previous symptoms it is likely to be an episodic outbreak. The treatment then depends on the severity of the infection (30). This is determined from the enquiry “Herpes Severity” which asks the user to input the outbreak frequency in number of outbreaks per year and also asks the doctor to decide if the symptoms can be considered particularly severe. The patient is considered to suffer from a severe herpes infection if six or more outbreaks per year have been experienced or if the symptoms are particularly severe. In this case the action “Suppressive Treatment” will activate, through the use of a state trigger that will be true if these conditions are fulfilled, advising the doctor to prescribe a suppressive treatment in the form of “aciclovir every day as part of a long-term treatment plan. Treatment is likely to require aciclovir twice a day for 6 to 12 months”. This action also contains advice on maintaining the infection and dealing with future outbreaks in the same way as the “Initial Infection” action. However, if the herpes infection is not considered severe but the patient has experienced previous symptoms the

action “Episodic treatment” will appear, also controlled by a state trigger. The treatment for episodic outbreaks is the same as for the initial infection and the advice is similar.

3.5 Testing

In order to test the doctor application a series of enquiries were included as seen in Figure 3.17. These collect the same information that the patient application collects in the final version of the system. This includes gender, symptoms, sexual history and all other information needed to complete the preliminary diagnosis and treatment stages. This allows testing of the doctor application separate from the rest of the system for a variety of different inputs. The first enquiry asks about the gender of the patient and reason for wanting a test. Depending on the answer the application moves to either the male or female branch.

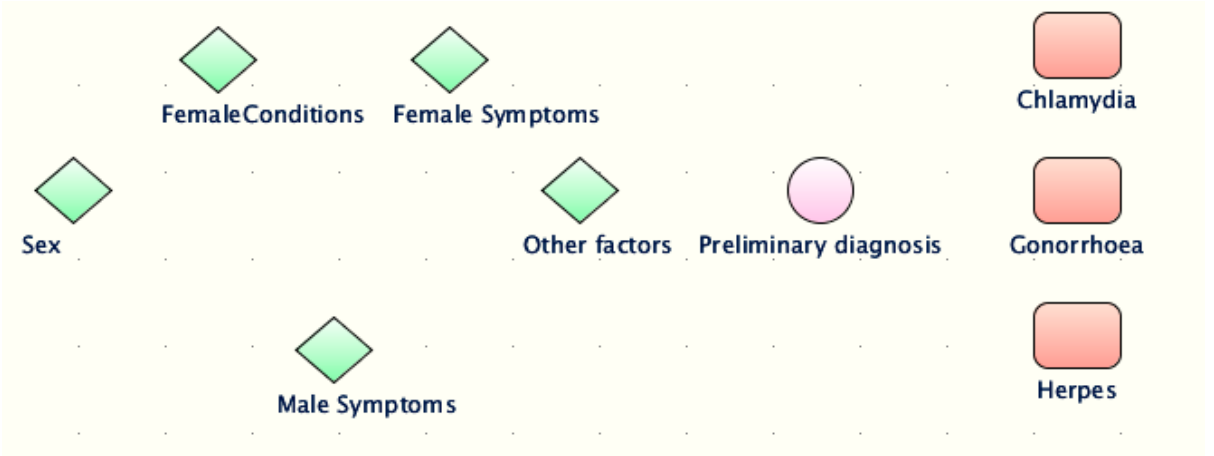


Figure 3.17 Series of enquiries used for testing doctor application

The enquiries “Male Symptoms” and “Female Symptoms” are very similar but since there are some symptoms that are specific to male or female patient there are two separate enquiries. Both of these enquiries provide a list of symptoms that the patient may have experienced and all relevant symptoms can be selected as sseen in Figure 3.18.

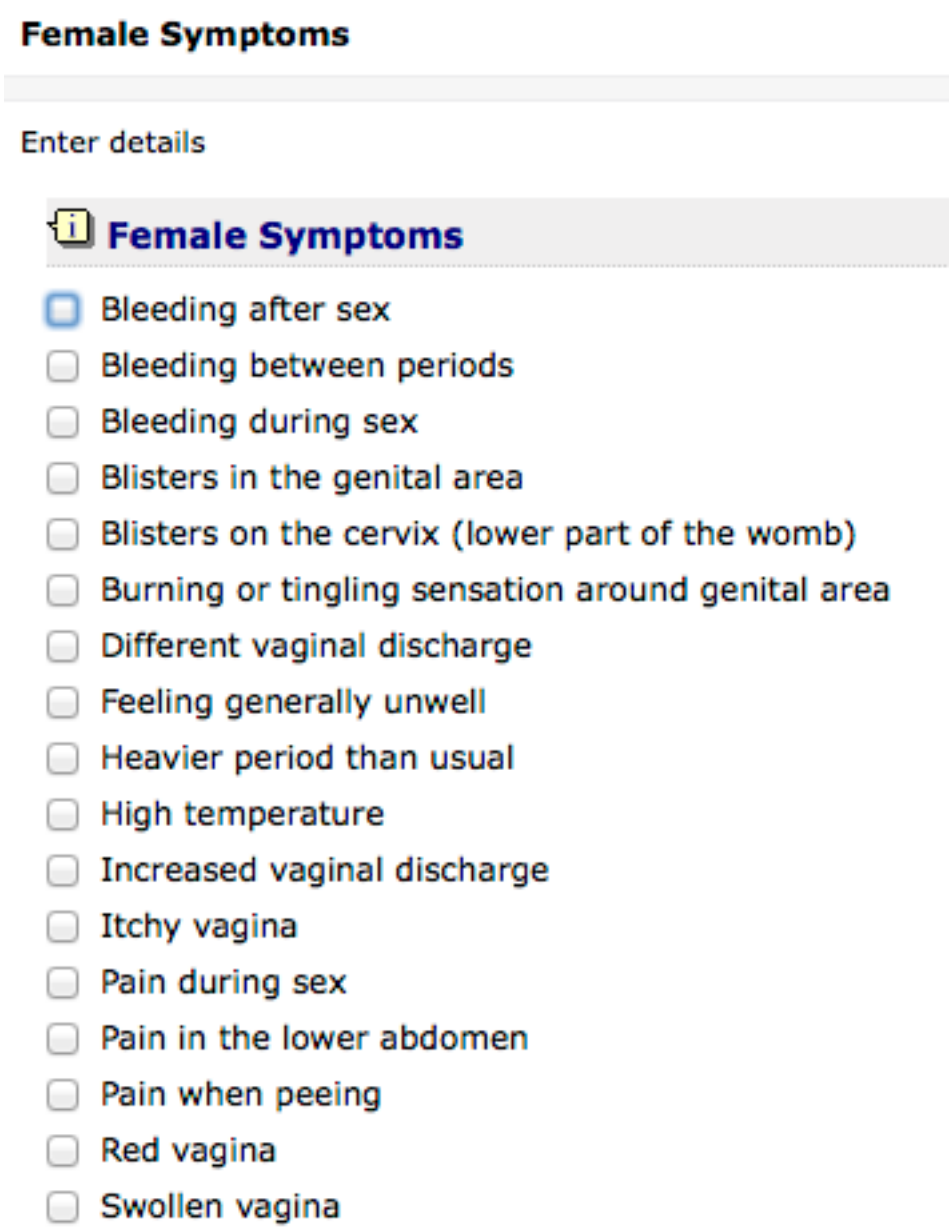


Figure 3.18 Enquiry about female symptoms used to test diagnosis decision

For female patients there is also the enquiry “FemaleConditions” which asks about other relevant conditions such as if the patient is pregnant, breastfeeding or on contraception. Once these enquiries have been completed there is one more enquiry, namely “Other factors”. In the current version of the application this enquiry only requests information about whether any previous sexual partner has been diagnosed with a sexually transmitted infection. Similarly to other parts of the applications, this series of enquiries also makes use of state triggers and preconditions to control the timing of the tasks. The first enquiry “Sex” is

launched as soon as the application starts. Once this enquiry is complete the process moves on to female conditions if the patient is female as this enquiry uses the state trigger "*gender = "Female"* " or to male symptoms if the patient is male and specific symptoms has been selected based on the state trigger "*gender = "Male" AND Reason = "Specific symptoms"* ". Finally, if the patient is male and a general check-up has been selected the process will skip the symptoms and move straight to the enquiry "Other factors" which uses the state trigger "*is_completed(FemaleSymptomsEnquiry) or is_completed(MaleSymptomsEnquiry) OR (Reason = "General checkup" AND (gender = "Male" OR is_completed(FemaleConditions)))*". This condition will be true when the relevant symptoms enquiry is completed or if a general check-up was requested it is true for a male patient or for a female patient who has completed the "Female Conditions" enquiry.

Tallis includes different methods of testing an application. The application can be verified meaning that Tallis looks for errors or warnings within the application and gives a verification report such as the one in Figure 3.19, where the doctor application has been verified to have no errors or warnings.

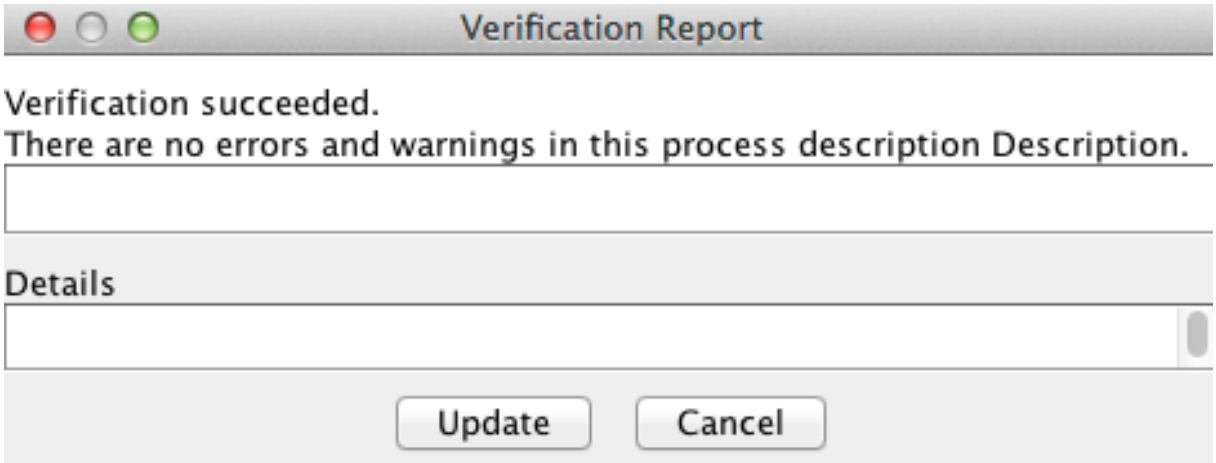


Figure 3.19 Verification report of doctor application

Furthermore, Tallis includes a tester where the application can be run offline. A screen shot of the Tallis Tester can be seen in Figure 3.20.

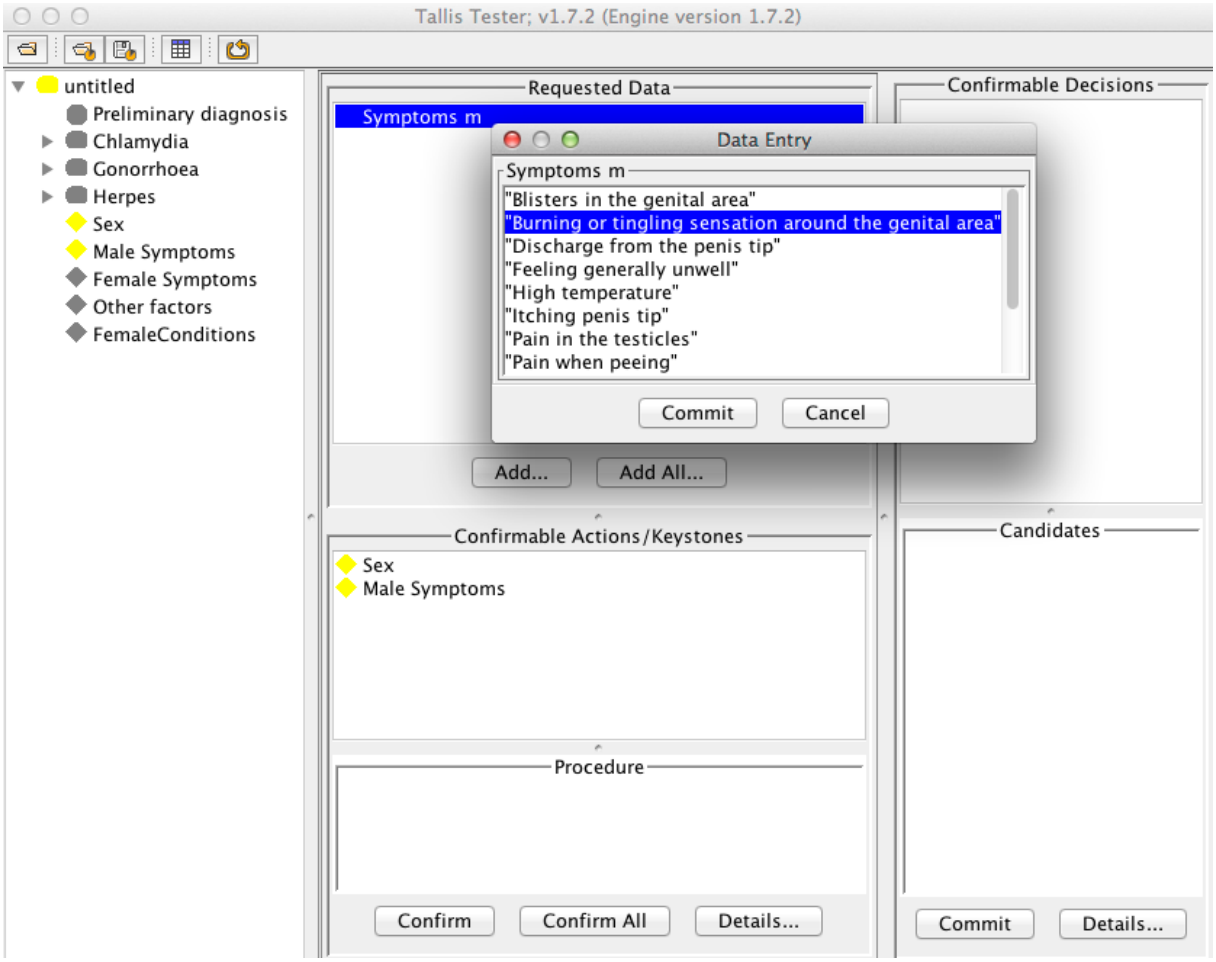


Figure 3.20 Screen shot from running the doctor application through the Tallis tester

The doctor application was developed in increments and every time new detail was added a series of tests were performed. First the app was verified using the verification tool. Then a variety of inputs were used to run the application both through the Tallis Tester and through the online Tallis Web Enactment to make sure it behaved as expected for all inputs. If any errors or bugs were found these problems were solved before running further tests and adding more detail.

3.6 System in practise

Implementing the doctor application presented in this section in practise requires some further considerations about the installation and maintenance of the system. The application is at this stage a prototype in need of further development before it can be used for clinical purposes.

3.6.1 Installation and launch

Before the doctor application can be used in practise it needs to go through some further steps. Firstly, more pathways need to be added to allow for more diseases to be included. Ideally all sexually transmitted infections should be covered in the application. Adding further diseases is made easy through the use of plans. Further plans can be added for the treatment of other diseases. The preliminary diagnosis decision would also need to be modified slightly to accommodate for additional candidates and arguments. In addition, some more detail is needed, particularly in the advice given to clinicians, which should also be clearly referenced. In order to achieve this and also to have the application as user friendly as possible it should be carefully tested by medical professionals and modified according to their feedback.

Once the application has been carefully reviewed and tested it will need to be downloaded to computers in clinics. The current version of the application uses 45kB of memory on disc. This predicted to more than double as five more diseases are added and it seems realistic to expect that the final application will take use 200kB of memory. This is a small amount on a standard machine and memory should not be a problem at the clinics as all information is stored on the database which is hosted on external servers.

3.6.2 Maintenance

In order to keep the advice up to date the application will need regular updates. New research can cause clinical guidelines to change (31). As medical guidelines change the advice in the application will need to be updated, as an important reason for using decision

support is to improve compliance with up to date clinical guidelines (32). It is likely that as long as the change in medical guidelines is not major, the modifications to the applications will be simple. For instance, changes in drug recommendations would mean changing only the text within one or a few actions. Larger changes could result in changes to the overall structure of the pathways, which would involve a significant amount of work.

Based on the work completed so far it is estimated that smaller updates will take no longer than 2 hours to complete by a software engineer, including testing, and larger updates will take up to 10 hours. Since significant changes to NICE guidelines require a process including drafting and public consultations where a short process takes 9-11 months (33) it can be assumed that major updates will be required no more than once per year and will be known well in advance. Smaller updates, where details of current guidelines are changed according to s so called “interim process for rapid updates”, which normally takes around 23 weeks to complete (34). Therefore, the most number of relevant updates per year is two smaller updates and one larger in order to keep the system up to date with current guidelines. In addition to updating advice and guidelines in the application there should be regular reviews where the system is updated based on feedback from the medical professionals that use the app.

Furthermore, every time detail in the application changes it needs to be tested carefully. Tests should be done for a large range of inputs such as to ensure that all pathways work properly. Testing the system is likely to require even more time than making tha actual updates. Ideally, both software experts and medical professionals should perform tests. It is estimated that the total time spent on developing and testing each update will be at least one full working day for a software engineer for a small update and longer for larger updates. In terms of cost, this means that to keep the application up to date a software engineer needs to be employed for at least five working days per year, two days for each of the expected small updates and another three days for a larger update. Finally, when the app has been updated the latest version will need to be distributed to all the clinicians using the system.

3.6.3 Conclusions

In conclusion, implementing an application like the one presented in this section will require some additional work, both by software experts and medical professionals before the product is ready to launch. However, a functional prototype has been completed which can be built upon to create an application that can be used in a clinical setting. This will be a worthwhile investment since in the future this doctor application can simplify the patient pathway through clinic care by providing decision support for the medical professional and thereby save both time and money.

3.7 User Experience of Doctor Application

The look and feel of the Doctor Application can be changed. This subsection explores these options.

The doctor application should be intuitive to use. The application view should be uncluttered and the number of button clicks through the application should be minimised.

Screenshots of a Tallis application are presented in Table 3.1. The look of the application is the default for Tallis applications. Several application templates are available, stored in the /usr/local/apache-tomcat-7.0.50/webapps/tallis-enactment-1.7.2/templates folder.

3.7.1 Customisation

There are several files that change the look and feel of the Tallis application. These files do not affect how Tallis works.

'tallis-enactment-1.7.2/applications/footZone/application.properties' affects the four parameters which define the highest level parameters.

Table 3.1 Tallis look and feel parameters

path	The name of the folder of the application.
welcome.page	Links to index.html, a HTML document which defines how the main page of the application looks.
title	The title of the application
enactment.template	Defined the template used.

Templates can be customised by adding a new template file to ' apache-tomcat-7.0.50/webapps/tallis-enactment-1.7.2/templates'. The templates take the form of several java documents.

'template.properties' defines the layout of the page. This document can call upon other documents for the specifics of certain elements. For example, the default template calls upon 'layout.jsp' to insert components into the page, and format.css and layout.css to specify where the elements should be on the page.

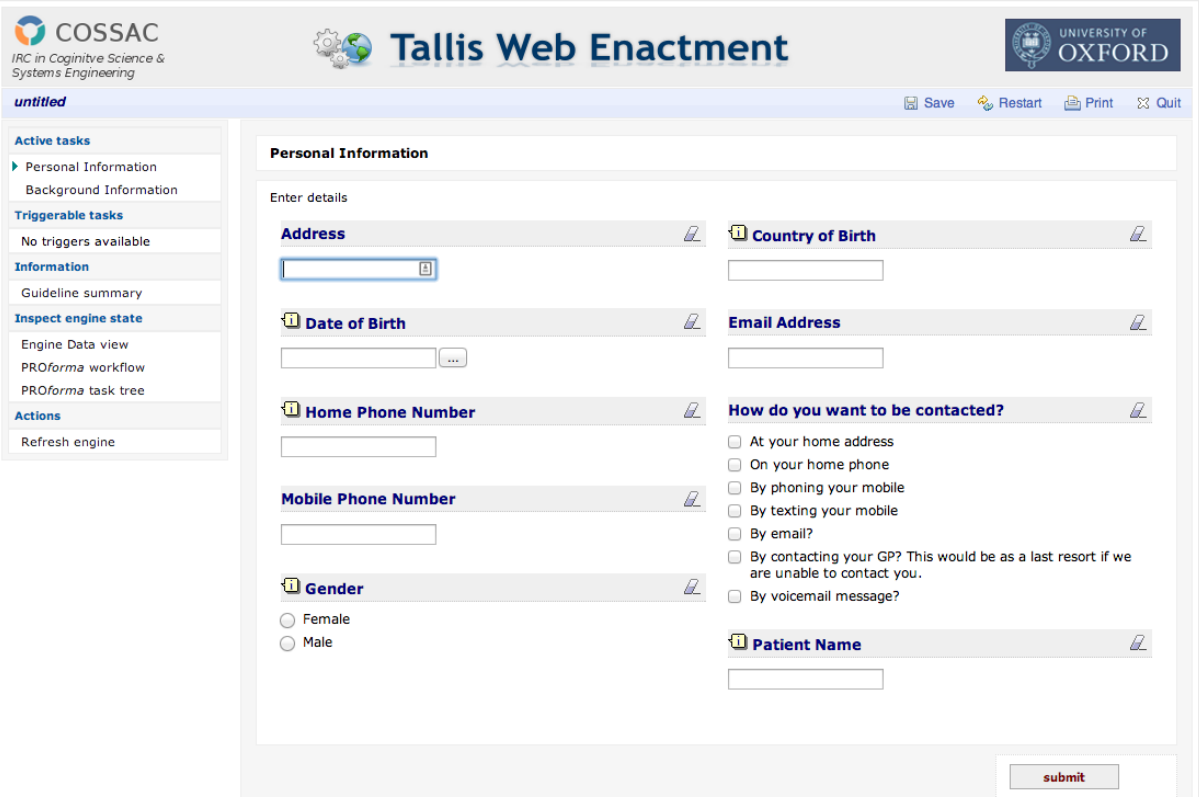


Figure 3.21 Tallis Web Enactment

4 Hosting

The patient website and the doctor application are accessed over the Internet. They must be running on computers connected to the Internet from which users can access the applications. Such computers run server software and are known as servers.

The database, which stores patient information, also needs to be hosted.

This section describes the specific hosting needs and looks at solutions.

We currently have server space on OpenClinical's servers. However, alternative options that can deal with increased user numbers must be explored.

4.1 Hosting risks

The application needs to be available to users constantly. This is especially important due to the medical nature of the application.

The risks associated with hosting the application are presented in a risk register, Table 4.1. The risks can be calculated using the risk matrix, Figure 4.1.

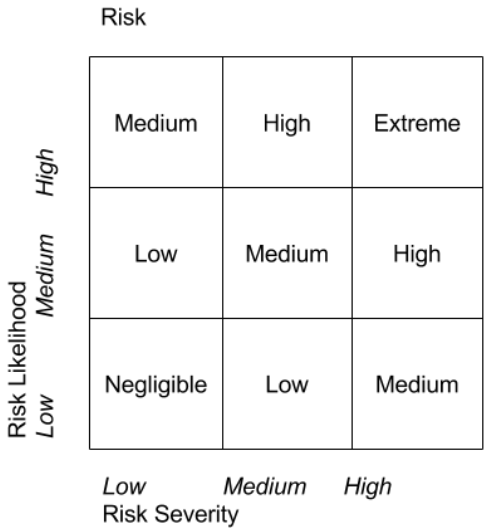


Figure 4.1 Risk Matrix

Table 4.1 Risk register for hosting a web service

Risk	**Likelihood**	**Severity**	**Action to Mitigate Risk**
Reduced service at peak times	H	M	Make sure that servers have enough bandwidth to cope with spikes in application use.
More users than anticipated	L	H	Measure number of application users and plan to increase application bandwidth before it becomes an issue.
Problems due to hosting software issues	M	H	Keep software updated. Employ people to maintain servers. Keep backup servers.
Problems due to hardware issues	L	H	Upgrade hardware as required. Keep backup servers. Employ people who are able to fix computer hardware.
Local power cuts	L	H	Have offsite backup servers.
Physical damage to servers	L	H	Keep servers away from places where they are likely to be damaged by being knocked over or by having water spilt on them.

			Keep servers locked so people cannot tamper with them
Servers damaged by natural disaster	L	H	Keep servers out of basements that may be flooded.
Servers targeted by cybercriminals	M	H	Invest in security measures.

4.2 Hosting needs

The application should be hosted in a way that allows for easy scaling of bandwidth and database storage size. This will allow for spikes in demand to be met and will allow for an expanding user base.

The servers should be reliable and perform well under high user loads, with near constant availability. This allows the service to be accessed when it is needed. Server reliability is also important from a user experience standpoint - if a web service is often unavailable users will become frustrated and are less likely to use the service.

The servers should be stored in a way that minimises chances of physical damage to them and software and hardware should be regularly maintained.

4.3 User load

The number of people in Oxford between the ages of 15 and 35 is 65 500 (35). 90% of all STI cases occur between these ages, as shown in Table 4.1.

4.3.1 Bandwidth needed

Monthly bandwidth is calculated to be 4.32 GB.

Monthly bandwidth breakdown:

$$Monthly\ bandwidth = \#\ page\ views\ per\ day * 30 * Average\ page\ size * \#\ pages\ visited$$

Number of page views per day: Assuming all people between the ages of 15 and 35 get one STI test per year, there will be on average 180 page views per day.

Average page size: A page size of 200 KB has been assumed. This number was decided on by looking at the page sizes of a selection of pages from The Barts and East London Sexual Health website (36), which is similar in style and format to the patient website. They were measured to be 193.7 KB (37), 186.4 KB (38) and 161.5 KB (39).

Number of pages visited per user: The number of page views per user was estimated to be four.

4.3.2 Database size

The database entry per person is estimated to be 100 bytes. If everybody under the age of 35 in Oxford creates an entry, the total database size would be 6.55 MB.

4.4 Server software

Our application is a Tallis application, which is written in Java. We therefore need software that can host Java applications.

Open Clinical's servers run Apache Tomcat, an Open Source web container used to deploy Java web applications.

4.5 Hosting options

Physical servers can be bought and run, or server space can be rented from third party groups.

Our application is likely to have varying use patterns; the service is likely to be used less during the night, for example.

Physical servers are constantly running and will have high running costs despite the hardware being mostly idle. They also have large set up costs, are complex to set up and maintain and are susceptible to local power cuts.

Server space is available from several companies such as rackspace.co.uk and Amazon Web Services. These offer several advantages over owing physical servers. Scalable server time can be rented; giving reliable and secure server time that is paid for in accordance with what is used.

This server space is scalable, meaning that the increased need for database size and bandwidth caused by the expansion of the application can be met.

The risks presented in Section 4.1 are taken on by the hosting company, reducing the cost and time involved with risk mitigation.

Physical space is not needed to store server hardware and a hardware maintenance team is not required

A study carried out by IDC, sponsored by Amazon found that renting server space though Amazon's Web Service found 72% savings on deploying the same resources on site (40).

Rented server space is more appropriate for this project given

4.6 Domain name

Each computer connected to the Internet is assigned an IP address. This unique address allows computers to communicate with one another. To save users from having to type in an IP address, a server's IP address can be associated with a domain name (such as http://www.sexualhealthoxford.nhs.uk/).

4.6.1 First level domain

The first level domain refers to the leftmost part of a URL. There are several first level domains to choose from, such as .com, .co.uk and .org. Each first level domain implies

something about its content. .com URLs are the most common and are likely to be the first tried by users. .co.uk imply the service is based in the UK and .org indicates an organisation.

An NHS first level domain, .nhs.uk, can be applied for (41). These domain names are free and take 1-2 days to register.

All NHS websites must have an nhs.uk domain name to make them a recognisable part of the NHS brand.

4.6.2 Choice of domain name

The choice of domain name depends on the nature of the organisation. If the application is to be used by an NHS clinic then the .nhs.uk first level domain would be appropriate. If not, a recognisable first level domain such as .co.uk or .org would be appropriate.

Domain names are cheap. For example, sexualhealthoxford.com can be purchased for £6.99 per year (42) (Figure 4.2 The price of domain names). To ensure that users can easily find the service, all common domain names could be bought. A main domain name, such as www.sexualhealthoxford.org could be chosen and all other URLs could link to that. Having control of domain names similar to the main one also reduces the likelihood of phishing, where fake websites which look like the target website are set up in order to steal user information.

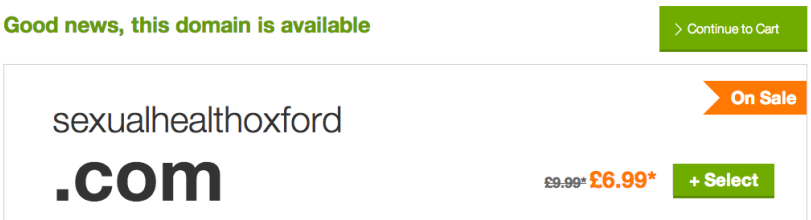


Figure 4.2 The price of domain names

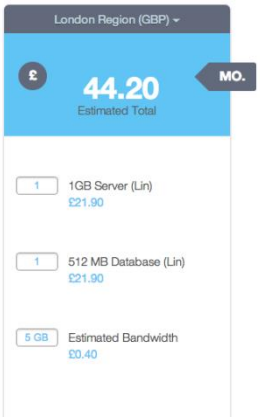


Figure 4.3 The cost of hosting

4.7 Cost of hosting

The cost of hosting the application and database on rackspace.com is £44.20 month (43). This is shown in Figure 4.3 The cost of hosting. This value is based on the estimated bandwidth and database size needed, as laid out in Section4.3.

5 Database

The web application has two distinct parts; a website accessed by the patient where personal information and symptoms are imputed and a website accessed by the doctor, where diagnosis decisions are made and best care practices are recommended. The patient's information must be stored in a database after it is inputted and the same information must be accessible from the doctor's side of the application.

5.1 SQL

SQL is a language designed for manipulating data in databases.

MySQl is an open source database management system, and offers tools that allow users to manipulate databases. MySQL was chosen as the database management system because it is free, widely used, scalable and reliable (44).

5.2 Communication between Tallis and Database

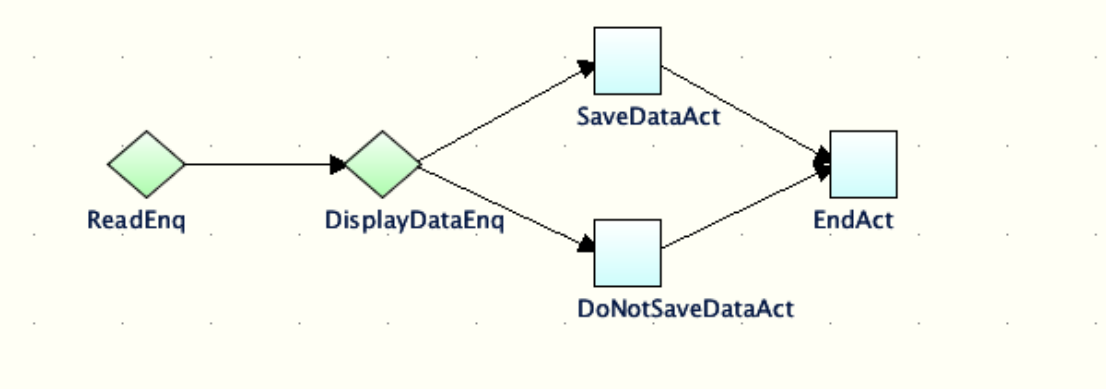


Figure 5.1 Read Enquires in Tallis

Information can be collected from or stored in the database in Tallis using collecting data enquiries and writing data action tasks.

These tasks communicate with a MySQL database as defined in an XML mapping document.

This mapping document carries out SQL read or write instructions when the Tallis software carries out certain enquiry, action or decision tasks. An example of an enquiry in Tallis is shown in Figure 5.1 Read Enquires in Tallis.

The elements that we use referred to as actionWriters and enquiryReaders.

5.2.1 actionWriters

These take the form:

```
<!--  DataWriterAction -->
<actionWriter taskName="SaveDataAct">
  <preparedSQLStatement dbName="db_test"
    params="Patient_Name Patient_Age Patient_ID">
    UPDATE tblPatientData SET
      patientName = ?, patientAge = ?
    WHERE patientID = ?
  </preparedSQLStatement>
</actionWriter>
<!--  End of DataWriterAction -->
```

Figure 5.2 actionWriters

taskName refers to the name of the action task in Tallis, and in this case the SQL statement adds the Patient_Name, Patient_Age and Patient_ID to the database.

5.2.2 enquiryReaders

These take the form:

```
<!-- DisplayDataEnq -->
<enquiryReader taskName="DisplayDataEnq" dataItem="Patient_Name">
  <preparedSQLStatement dbName="db_test" params="Patient_ID">
    SELECT patientName FROM tblPatientData WHERE patientID = ?
  </preparedSQLStatement>
</enquiryReader>
<enquiryReader taskName="DisplayDataEnq" dataItem="Patient_Age">
  <preparedSQLStatement dbName="db_test" params="Patient_ID">
    SELECT patientAge FROM tblPatientData WHERE patientID = ?
  </preparedSQLStatement>
</enquiryReader>
<!-- End of DisplayDataEnq -->
```

Figure 5.3 enquiryReaders

These SQL statements search the database db_test and return the patientName and patientAge for the inputted patientID.

5.2.3 decisionWriters

These allow the results of Tallis decisions to be recorded to the database. This information is not directly needed in the application and but could be stored for auditing purposes.

5.2.4 Defining the Database Location

The location of the database is defined in the 'tallis-enactment-1.7.2/WEB-INF/conf/GlobalConnections.xml' document.

This mapping document must be linked to in the main application. This is done by editing the Tallis application (tallis-enactment-1.7.2/applications/PatientSide/proforma/Patient_app.pf) and adding the line ''folio.xmldbmapper.mapping=customisations/testMapping.xml', given that the mapping document is called testMapping.xml and is stored in a folder named 'Customisations' in the application folder.

5.3 Database security

As a third party company hosts the database, they handle security. For example, security features offered by Amazon Web Services Security include HTTPS to allow secure connections to the server using SSL, firewalls and encrypted data storage (45).

6 Database Backup Scheme

If there is loss or corruption of the encrypted patient data stored in the database, an effective backup scheme is needed in order to restore the database with minimum loss of patient data. Following section 5.1, it has been decided that SQL (Standard Query Language) is to be used for the database and therefore the following design is specific to this language. Several different backup methodologies (including their applicability to our application) are outlined below. A decision is then made on which method to adopt for our database and instructions are provided on how to implement the recommended backup scheme.

6.1 Simple recovery model

This method backs-up the entire database including part of the transaction log[2] so that a complete database can be recovered after a full database backup is performed.

Under the simple recovery model, after each backup the database is exposed to potential loss of data if a disaster were to occur. Work-loss exposure increases over time between backups as is illustrated in Figure 6.1.

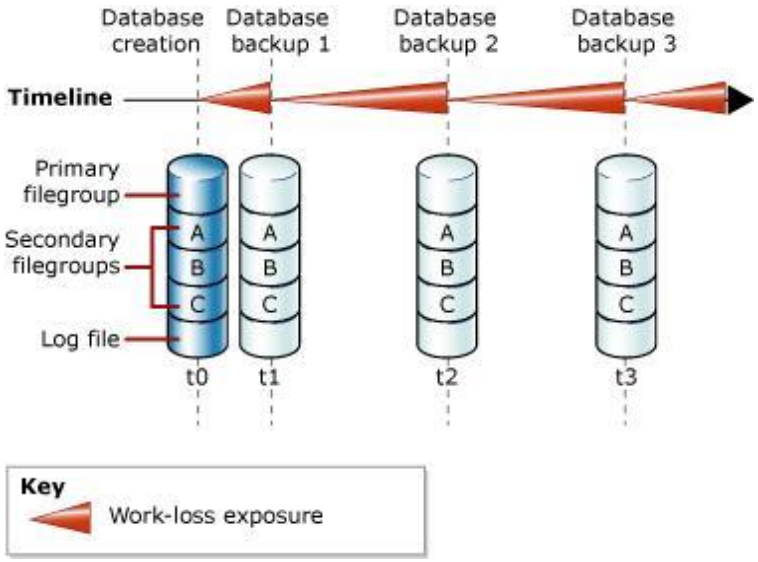


Figure 6.1 Work-loss exposure for the simple recovery model.
http://www.technet.microsoft.com

[2] A transaction log is a history of actions executed by a database management system to guarantee ACID properties (Atomicity, Consistency, Isolation, Durability) over crashes or hardware failures. Physically, a log is a file of updates performed on the database and stored in a stable storage space.

From this figure it can be seen that a full database backup performed in this way is not suitable for this application. If a crisis were to take place shortly before a database back up was due, the loss of patient data would be unacceptably high.

6.2 Full recovery model

The work-loss exposure can be reduced by updating the ‘Simple Recovery Model’ to a ‘Full Recovery Model’ where transaction log backups are used to prevent data loss. The advantage of using log backups is that point-in-time recovery is possible i.e. the database can be restored to the specific time contained within a log backup. However, using log backups requires extra storage space and increases restoration-time and complexity.

The optimum interval of logs will depend on factors such as importance of data, the size of the database and the workload of the server.

6.3 The differential backup

A differential backup is based on the most recent, previous full data backup and captures only the data that has changed since the last backup. The full backup upon which a differential backup is based is known as the ‘base’ of the differential and this full backup can serve as the base for a series of differential backups. In every GAM interval (4GB section) of each data file in the database there is a page known as a differential bitmap that has the ability to track which extents (portions) of that 4GB section have been altered since the last full backup .A differential backup scans through these bitmaps and backs-up the extents that are marked as changed. The bitmaps are only reset by the next full backup so as more of the database changes between consecutive full backups, the differential bitmaps will flag more of these changes and successive differential backups will become increasingly larger.

The mechanism for a differential backup is shown in Figure 6.2.

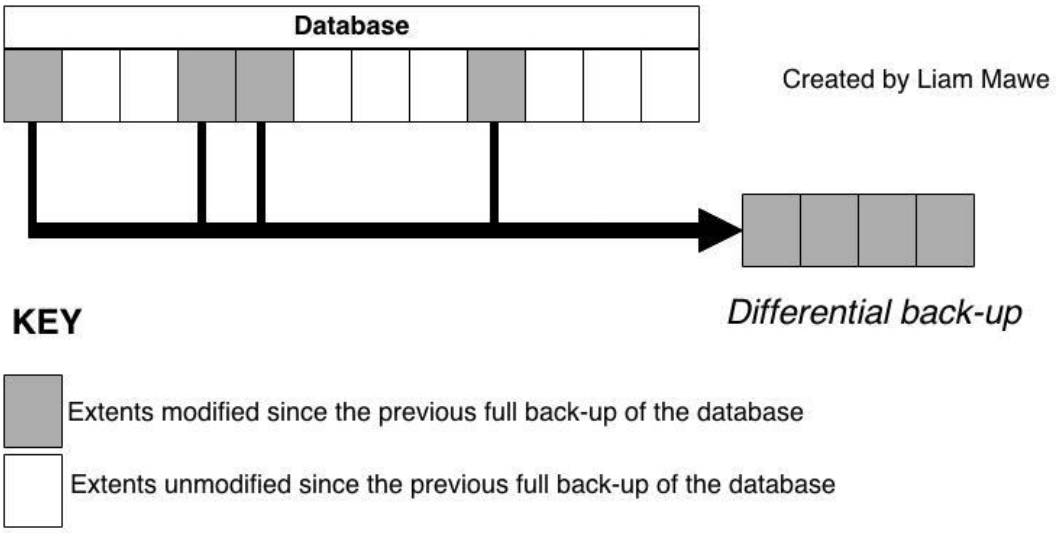


Figure 6.2 Illustration of the differential backup method

The advantage of using a differential backup is that it is usually significantly smaller than the base as only data that has been altered since the last backup is saved. This consequently makes differential backups less computationally expensive than the other methods. However, over time the differential backup can approach a similar size to the base. Therefore new full backups at set intervals should be established to ensure a differential backup system remains efficient. It should also be noted that before restoring a differential, the base must first be restored. Therefore restoring from a differential backup will necessarily take more steps and time than restoring from a full backup because two backup files are required.

6.4 Incremental backup

The incremental backup is similar to the differential backup with the exception that only altered data since the last incremental backup is saved. Conversely, the differential backup saves all altered data since the last full backup. Restoring from incremental backups will consequently involve more steps and time than restoring from a differential backup.

6.5 Decision for application's backup method

The differential backup method is well suited to the design of our application; the majority of the stored patient data will be unchanging and using this method will mean improved computational efficiency in backing-up the database. A system of incremental backups could have been acceptable but as the data is not memory intensive and because care will be taken to restrict the size of the differential, there will be few benefits acquired from using the incremental system. Moreover, each incremental backup is dependent upon the prior one being good. If one backup archive corrupted, then all backup files after that would become inoperable. A differential backup on the other hand contains all the changes from the original backup so each differential needs only the original to function. Following these reasons, the decision has been made to follow a system of differential backups over an incremental system.

To ensure that the size of the differential does not get too large, a system of differential backups should be combined with a variation of the full recovery model for optimum results. The full recovery model can be used but with differential backups to reduce the number of transaction log backups in the full recovery model.

Backup medium

Disk drives and tape drives are the two most widespread physical mediums on to which database backups are stored. The advantages and disadvantages of both methods are summarised in the following table.

Table 6.1 Relative advantages of disk and tape methods as the physical media for the database backups

Method	Advantage
Tapes	• **Durability** – Tape cartridges are comparatively simple to disks

	which contain sensitive moving parts like heads and spindles. If dropped, the tape cartridge is more likely to survive the fall as the tape has no internal drive heads or spindles to break upon impact. • **Increased portability and safety** – A tape has increased portability meaning it can be kept safely in ordinary storage or can easily be transported off-site. • **Cheaper for storing large data** – The initial cost of setting up a tape storage method is high but afterwards it is very simple and cheap to add extra tapes meaning the costs are comparatively lower for storage of memory-intense data.
Disks	• **Fast random access / restore times** – Tapes store data sequentially whereas disks have the advantage of random access storage which greatly increases data access and reduces restore times, particularly when restoring individual files or small amounts of data. Backups performed to a disk eliminate the time it takes to mount a tape, search for the correct position and wind forwards and backwards to locate the data you want to restore. • **Cheaper for storing small data** – The initial costs of setting up a disk are much smaller than the tape alternative which means for non-memory intensive data sets, a disk medium will be cheaper.

For this application, the decision has been made to use a combination of disk drives and tapes in order to exploit their differing strengths. Tapes' extra durability and ability to be kept off-site mean that they can be considered a more reliable form of storage but not suitable for more regular backups because of the additional time taken to store data when compared to disk drives. Additionally, storage methods involving disks are cheaper to establish than

equivalent tape methods for backups that are not memory-intense. Therefore it would make sense to use tapes for the database's weekly full backups and disk drives for the regular differential and transaction log backups.

This system also makes sense with regards scalability. Over time, the size of the database will increase as more patients are added to the database. This does not affect the size of the differential backups or the transaction logs and so the disk space will not have to be increased. This does however, affect the size of the full database back up but as it is simple and cheap to add extra tapes, this will not cause issues in the future when the database increases in size.

6.6 Implementation of a database backup maintenance plan

The optimum level of differential backups will depend on factors such as importance of the data being saved, the size of the database and the processing power of the server and medium onto which the data is being saved. It can be assumed that the importance of the patient data is consistently high but decisions involving exact timings must be decided for each medical centre depending on their own specific needs. This maintenance plan has been created for use with Warrington GUM clinic[3].

A transaction log should be taken as frequently as possible to minimise data-loss in the event of a crisis. As the data to be saved is not memory-intensive (approximately 256 bytes per patient)[4], the system will be able to cope with creating a new log every 5 minutes with only standard processing power. This is true even in the worst case scenario when several patients are storing data simultaneously.

[3] Data acquired from visit to Warrington GUM Clinic on 12/12/2013 by analysing procedure and interviewing staff members.
[4] This estimate is based upon example patients. An average of 20 data items per patient to be stored in database, each data item on average 10 symbols long and each symbol is one byte, therefore approximately 200 bytes per patient. However, data is encrypted in blocks. Assuming 128-bit blocks, 200 bytes of plaintext becomes 256 bytes of ciphertext.

Daily differential backups should provide an acceptable compromise between limiting the number of logs between differential backups and not overloading the system with too many differential backups (which could cause crashes). Performing a weekly full backup will ensure the size of the differential is kept adequately small at around 130 Kbytes[5]. Table 6.2 summarises these decisions with a sensible maintenance plan for a secure backup system.

Table 6.2 Maintenance plan for potential backup system for use with Warrington GUM clinic

Day	Event
Monday - Saturday	Differential backup to disk (Performed daily). Between daily differential backups, back up transaction log every 5 minutes to disk.
Sunday	Full backup to tape. Between full or differential backups, back up transaction log every 5 minutes to disk.

NB: The spacing between events has been chosen so that the number of transaction logs between differential backups is roughly even.

6.6.1 Using SQL Code or wizard to implement backup maintenance plan

Maintenance plans can either be set up manually using code or using the SQL software's built-in maintenance plan wizard. To illustrate both methods, there are first examples of how automated regular backups can be established with code, followed by automatic deletion of unwanted backups with a wizard. Either method is acceptable for both automatic creation and automatic deletion of the backups.

[5] Warrington GUM clinic sees approximately 40 patients per day. For each patient there will be 2 changes to the database requiring 256bytes; the initial change when the patient fills in the form online and the second when the patient attends a consultation at the clinic. The clinic is open 6 days a week so one expects around 240 patients per week. *Approximate total bytes required per week = 240 x 2 x 256 = 122880bytes ≈ 130 Kbyte.*

The following code gives an example of how the three events in Table 6.2 could be implemented to the applicable medium with an SQL script;

6.6.1.1 SQL code implementing weekly full database backups saved to tape

```
#Create a full database backup to a tape.

CREATE EVENT fullbackup_weekly
   ON SCHEDULE
     EVERY 1 WEEK
   COMMENT 'Creates weekly full backup of PatientDatabase which is
saved to a tape'
   DO
     BACKUP DATABASE PatientDatabase
            TO TAPE = '\\.\Tape0'
#Full backup saved to an arbitrary tape called‘Tape0’
            WITH NOINIT,
#NONIT indicates that the backup set is appended to the specified
#media set, preserving existing backup sets.
                          NAME = 'Full Backup of PatientDatabase’;
GO
```

6.6.1.2 SQL code implementing daily differential database backups saved to disk

```
#Create a differential database backup to a disk, appending the
#backup to the backup device containing the full database backup.

CREATE EVENT diffbackup_daily
    ON SCHEDULE
      EVERY 1 DAY
    COMMENT 'Creates daily differential backup of PatientDatabase
which are saved to a disk'
    DO
     BACKUP DATABASE PatientDatabase
                  TO DISK = 'Z:\SQLServerBackups\PateintDatabase.Bak'
#Saved to an arbitrary disk space ‘SQLServerBackups’
          WITH NOINIT,
#NONIT indicates that the backup set is appended to the specified
#media set, preserving existing backup sets.
       NAME = 'Differential Backup of PatientDatabase';
    WITH DIFFERENTIAL;
GO
```

6.6.1.3 SQL code implementing transaction log backups saved to disk every five minutes

```
#Create a transaction log backup for
#the PatientDatabase_FullRM database to the previously created backup
#device ‘PatientDatabase_FullRM_log1’

CREATE EVENT logbackup_5mins
   ON SCHEDULE
     EVERY 5 MINUTES
   COMMENT 'Creates transaction log backups of PatientDatabase which
are saved to a disk'
    DO
       BACKUP LOG PatientDatabase
```

```
12              TO DISK = 'Z:\SQLServerBackups\PateintDatabase.LogBak'
13           WITH NOINIT,
14 #NONIT indicates that the backup set is appended to the specified
15 #media set, preserving existing backup sets.
16      NAME = 'Transaction Log Backup of PatientDatabase';
17 GO
```

6.6.1.4 Implementing automatic deletion of unwanted backups using a wizard

To avoid build-up of unnecessary back-ups, automatic deletion of unwanted backups can be employed. Provided is an example of how an SQL server maintenance plan wizard could implement this automatic deletion. The wizard is from 'SQL Server Agent', a Microsoft Windows service that executes scheduled administrative tasks.

Wizards are typically very intuitive. Step-by-step queries are provided through a pop-up and the user defines the maintenance plan required. The following screen shots illustrate how the wizard works, with 4 week-old backups being deleted daily. For this application, I suggest daily deletion of backups older than two weeks. This is the minimum required amount of backups that ensure there are always two complete backups of the database. With this method, if a crisis were to take place to the original database there are two backups that could restore the database; this means even in the unlikely event that the most recent backup is also corrupted, there is the previous backup which could completely restore the database to its state two weeks previously.

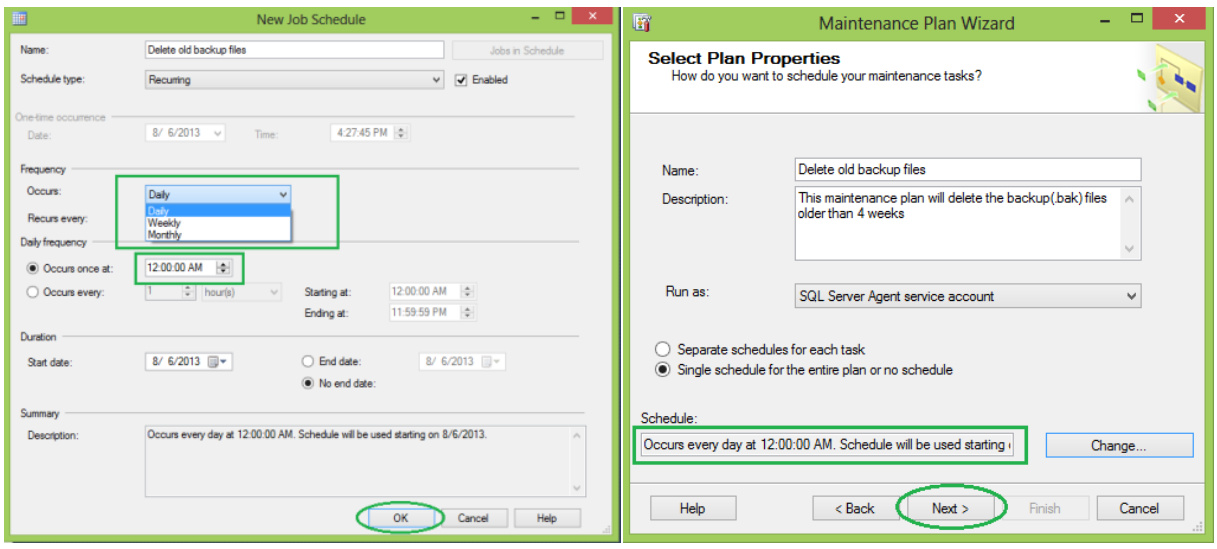


Figure 6.3 Screenshots of Microsoft's 'SQL Server Agent'.

7 Online Security

This application relies on the transfer of sensitive patient data online. The consequences associated with the interception or loss of this data are exceptionally high and a compromise of security could put patients' health at risk and result in costly lawsuits against the medical centre. An effective and thorough design for online security is therefore integral to the success of this application.

7.1 Encryption methodology

Encryption is an essential security measure in the design of this application. Once the patient data has been encrypted, it becomes incomprehensible to an attacker without the relevant decryption key and thus dramatically reduces the risks associated with intercepted data.

7.1.1 Introduction to public key encryption

A visual representation of the flow of sensitive data in our application is seen from Figure 7.1.

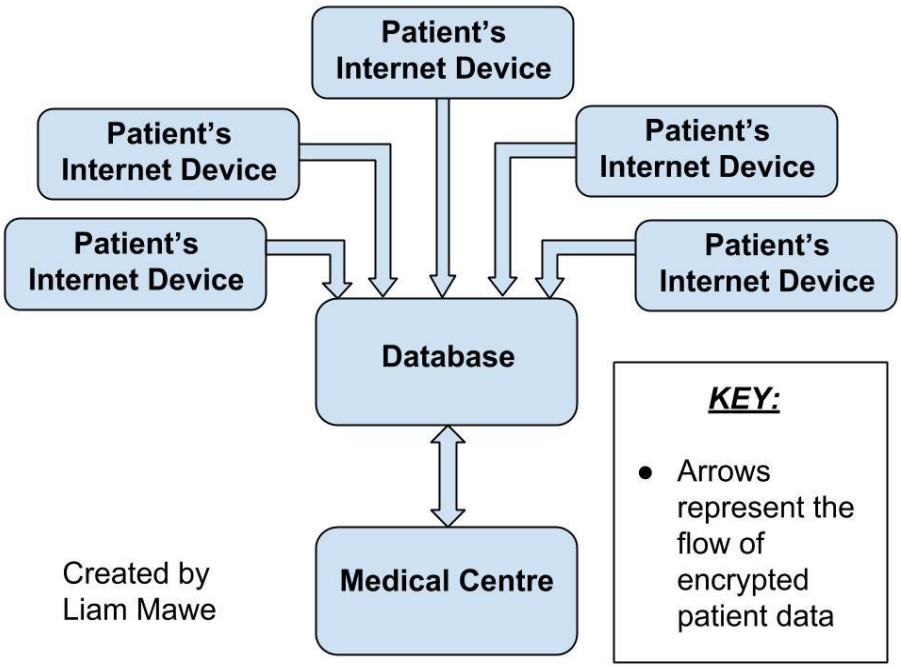


Figure 7.1 Visual representation of the flow of encrypted data

As can be seen, a method needs to be implemented that allows many patients to send encrypted data over the internet to the database, but that can only be decrypted by the medical centre. This is possible via a public key encryption method.

Public key encryption relies on the concept of asymmetric key algorithms i.e. the key used to encrypt the data (the public key) is not the same as the key used to decrypt it (the private key). There is no current efficient solution to these algorithms which derive from complex mathematical problems inherent in integer factorisation, discrete logarithm and elliptical curve relationships. As regards this application, the public key would be widely distributed to the patients and used to encrypt the results of the online form being sent over the internet. The private key is a secret password (typically 1024 characters or more) and is used to decrypt the data. Figure 7.2 gives a visualisation of the public key encryption process that would be implemented for use with this application.

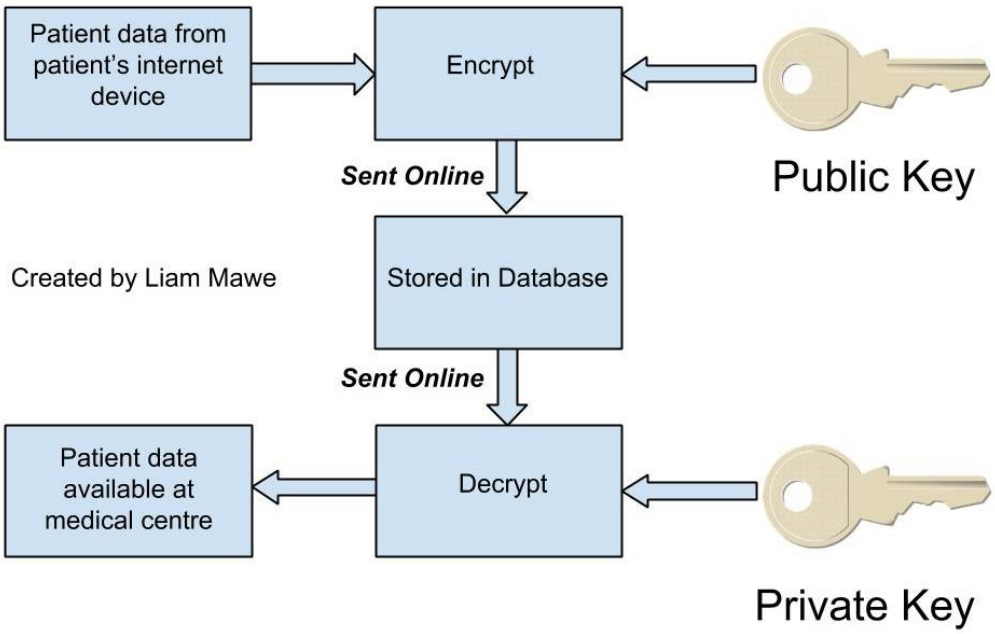


Figure 7.2 Public-key encryption visualisation

7.1.2 Available methods for public key encryption

There are various available algorithms that can perform public key encryption. After considering the RSA, DH, DSA, DES, 3DES and ECC algorithms (as they are the most commonly distributed methods for public key encryption), research supports using ECC (Elliptical Curve Cryptography) where possible.

The older generation algorithms (such as RSA, DH and DSA) are susceptible to sub-exponential attacks and in order to compensate for this, their key sizes must be substantially increased.[6] This makes the algorithms less efficient than their more modern counterparts and they can be disregarded for use with this application.

ECC is a newer alternative form of the public key cryptography and surpasses the DES and its upgrade 3DES, the main advantage being its efficiency in offering the same level of security for smaller key lengths. The mechanism of ECC is complex but its increased efficiency over older public key encryption methods stems from its algorithms deriving from elliptic curves operating over finite fields (46). For example, a 224-bit ECC key equates to the same security as a 2048-bit RSA key (47). ECC is therefore preferred for use with this application as the shorter key lengths require less computing power meaning faster and more secure connections are available to patients wanting to use the website on-the-go with their smart phones or tablets.

7.1.3 Disadvantages of public key encryption

The advantage of the public key method is that any patient can send encrypted data to the database without then obtaining decryption capabilities. However, the method has some notable disadvantages that need to be considered before reaching a decision on whether the public key encryption method should be adopted:

[6] A key specifies the particular transformation of plaintext into cipher text. The key size is simply the size of this key measured in bits. For further information regarding sub-exponential attacks see [32].

1. Since anyone can encrypt the data, a history of query trapdoors can be obtained and then used to determine which keyword was being searched for.

2. The added complexity of the asymmetric key algorithms when compared to symmetric key algorithms means that the public key method is less computationally efficient than symmetric key primitives and consequently also makes searching less efficient.

7.1.4 Conclusions for public key encryption

Despite these disadvantages, the public key method is still the recommended encryption technique for use with our application.

The first of the disadvantages can be avoided if the only enquiry to be made is the ‘Patient Name’. This single enquiry could extract all the information saved for that patient and run it on the Doctor’s Tallis application. If the only enquiry is ‘Patient Name’ a hacker would first have to know the patient name to be able to extract this information, and so no knew knowledge could be obtained. Compare this to a method involving separate enquiries such as ‘Chlamydia Result’ or ‘Does patient suffer from Pelvic Inflammatory Disease’ for each patient. In this second, undesirable method, a hacker might be able to extract sensitive information about a patient based on the keywords used in searching the database.

As for the second disadvantage, a reduction in computational efficiency from using a public key method over alternative encryption methods is a necessary compromise such that anyone can send encrypted data without then gaining decryption capabilities. Moreover, in 7.2.2 it will be seen that adopting a TLS (Transport Layer Security) connection would mean once authentication has been established between the patient and medical centre’s server, symmetric cryptography can be employed between the parties which would increase the computational efficiency of data transferral.

7.2 Transport Layer Security

As seen in Figure 7.1, sensitive patient data is sent online from the patient application to the database and then back and forth from the database to the medical centre. Transport Layer Security (TLS) is a protocol that safeguards the online communication between the patient application and the medical centre's server.

7.2.1 Man in the middle attack (MITM attack)

Numerous methods are employed by hackers to obtain private information online. This section introduces one such threat in order to exemplify to non-specialists how a hacker might intercept data and the importance of a secure online connection.

A MITM attack intercepts a communication between two systems. In the http transaction that would take place between the medical centre's server and the patient's browser in our application, the target for a MITM attack would be the TCP (Transmission Control Protocol). Once the TCP connection is intercepted the attacker acts as a proxy (intermediary connection), having the ability to read, insert and modify the data in the intercepted communication. A sound encryption method may stop a successful interpretation of the data between the patient and the database but a hacker will still always have the ability to corrupt the data between the patient and server. A visualisation of a MITM attack is provided in Figure 7.3.

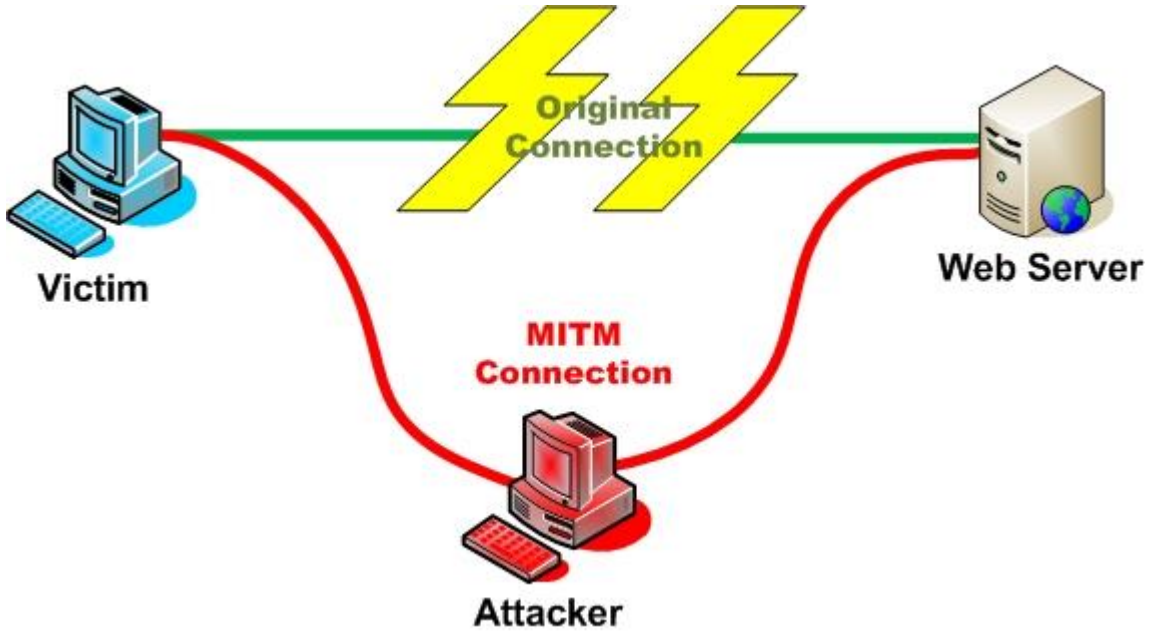


Figure 7.3 Man in the Middle Attack.
https://www.owasp.org/images/2/21/Main_the_middle.JPG

7.2.2 Introduction to TLS with this application

A TLS (Transport Layer Security)[7] protocol can be used to authenticate servers and clients so that decrypted messages can be sent between authenticated parties and reduce the likelihood of MITM and other attacks. It is based upon the principles of public key cryptography and, following 7.1.4 Conclusions for public key encryption , could therefore be an appropriate security method for use with our application.

During the TLS authentication process, a patient would send a message to the medical centre's TLS server and the server would respond with a digital signature in order to authenticate itself. The recipient of the digitally signed message can verify both that the message originated from the medical centre, whose signature is attached, and that the message has not been altered either intentionally or accidentally since it was signed. Once the digital signature is verified, the patient and server would perform an exchange of session

[7] For those with specialist knowledge: TLS (Transport Layer Security) is an overall security protocol and SSL (Secure Sockets Layer) is part of this protocol. SSL can be thought of as the old version of TLS with "TLS 1.0" being "SSL 3.1". I refer only to TLS as it has become the standard for the Internet Engineering Task Force (IETF).

keys and the authentication dialogue ends. The TLS-secured communication can then begin between the server and the patient using the symmetric encryption authentication process.

7.2.3 Digital Certificates

A patient would confirm the validity of the server's credentials with a Digital Certificate (DC). These are issued by a trusted certification authority (CA) and contain information such as the issuer's public key and digital signature.

The creation of a DC is relatively simple to achieve and could theoretically provide all the same safety benefits as a purchased DC from a certification authority. However, there are limitations of self-created DCs that would arise if the application were implemented in practise. All widely used internet browsers will flag an unknown DC to a patient attempting to communicate with the medical centre's server. Figure 7.4 shows an example of such a security warning from Google Chrome.

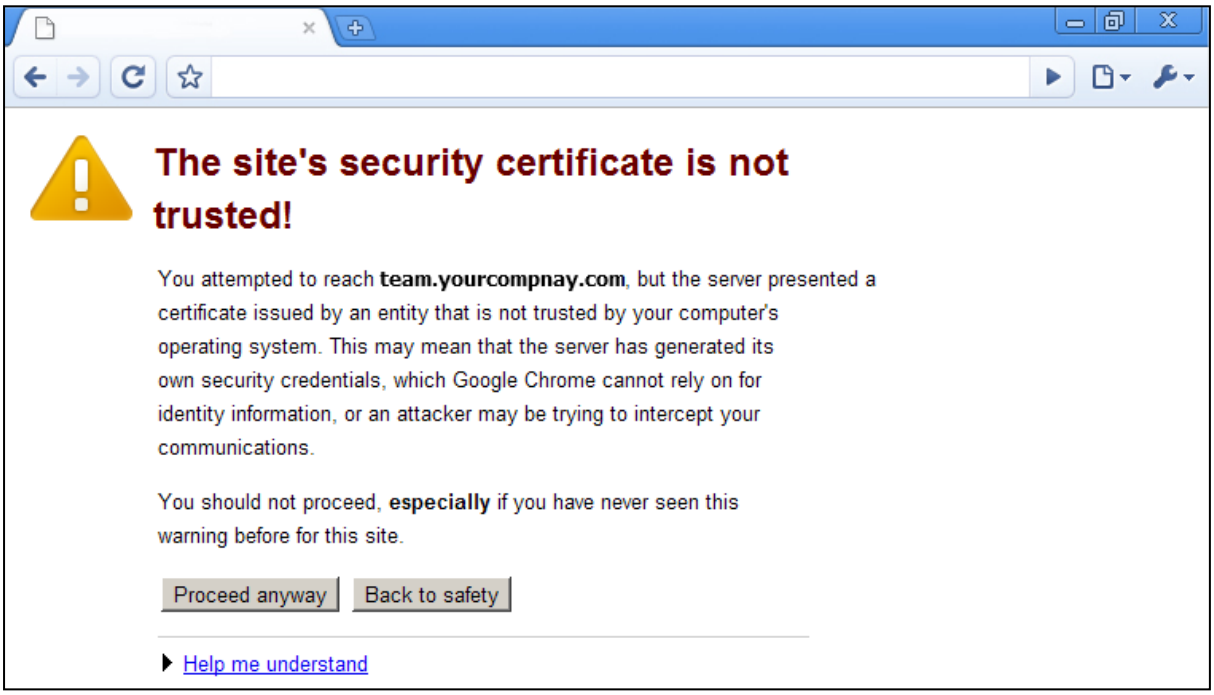


Figure 7.4 Google Chrome warning for a distrusted DC

Regardless of the actual security of the application's TLS connection, if the patient's browser flags a DC as untrusted they will be discouraged from sending their sensitive data online. Consequently if a TLS connection is required, the DC will need to be issued from a reputable 'Trust Centre' (e.g. AOL, Microsoft, Symantec), adding an extra variable cost to employment of this application.

X.509[8] certificates are the ITU-T (Telecommunication Standardization Sector) standard for public key cryptography and is the recommended format for DCs. X.509 certificates contain several required and optional attributes that enable the safe identification of a subject. The complete list of these attributes is too long to list here, but to summarise some of the key features, X.509 verifies; the validity period of the DC, the public key algorithm that is to be used, the signature algorithm ID used to create the digital signature and the extensions attached to the DC that can be used to store additional information such as KeyUsage or AlternativeNames.

The cost of purchasing a DC varies dramatically and is largely dependent on the features included with the package. Below are the key features that would be available from 'VeriSign' (part of the Symantec group) for one of their top-end packages priced at £745p.a. with a 2 year contract.

1. Extended Validation[9] (EV) certificates would trigger the green address bar to notify patients that we have a highly secure browser. See Figure 7.5.
2. Up to 256-bit encryption with 128-bit minimum encryption is available for encrypting the sensitive patient data being sent online.
3. The TLS connection supports the ECC encryption algorithm.

[8] Different versions (version 1, 2, and 3) of X.509 certificates have evolved over time to provide additional security and features. Only version 3 certificates are used in practise and consequently only X.509v3 certificates should be considered for this application.
[9] EV is a specific X.509 public key certificate issued according to an explicit set of identity verification criteria. These criteria require extensive verification of identity by the CA before a certificate is issued.

4. Vulnerability assessment and daily website malware scanning would help protect the website from hackers.

5. £910,000 warranty should security be compromised.

Figure 7.5 Example of Google Chrome's green address bar

7.2.4 Conclusions of purchasing a DC

The purchase of a DC package (such as the 'VeriSign' package given in the previous section) is advised despite the additional cost. A TLS connection initiated from a reputable company acts as a guarantee to medical centres and patients that patient data is communicated safely. The warranty will make investment of the application more attractive by reducing the financial risk associated with law-suits if there was a compromise of security. Additionally, such packages offer ECC encryption which complies with the recommendations outlined in 7.1.2 Available methods for public key encryption.

The addition of a green address bar and padlock icon in the patient's browser (resulting from an EV certificate) would raise patients' perception of security as they are widely trusted symbols of online safety. This is imperative to the application's success as if patients are aware of the high level of security involved with the communication of their sensitive data, they will be encouraged to use the online service.

8 Costs and Benefits: Holistic Approach

This report needs to contain some form of comparison between the costs and the benefits of this application to aid in the decision of whether to invest in this project. Traditional cost-benefit analysis will not be a suitable approach for this particular application demonstrated by the reasons below and supported by the following academic journals (48) (49).

1. Traditional cost-benefit analysis requires definite numbers on each side of the balance sheet to allow the comparison of costs and benefits. However the costs and benefits of healthcare are not normally expressed in comparable units. Patient wellbeing is fundamentally a nonmonetary value and therefore to attempt to monetise this kind of benefit for comparison to the costs would be illogical.
2. A cost-benefit analysis requires the costs and benefits of this application to be transferred to a present day value; this is too implausible with health related implications. [10]

Within '*Critique of Cost-Benefit Analysis, and Alternative Approaches to Decision-Making*' (48) the advantages of using a *holistic method* over the cost-benefit analysis are stressed, where costs as a whole (usually expressed in monetary terms) and benefits as a whole (often largely nonmonetary) are considered together, but are not expressed in the same units. This holistic method will be deployed in this report to aid with investment decisions, starting with a clear outline of the monetary costs and followed by the benefits of the application expressed in their most natural form (i.e. not converted into monetary terms).

8.1 Costs

Early in the project, a spreadsheet was created using Microsoft Office Excel such that cost estimations could be continuously updated as of when they were discovered. Formulas

[10] To exemplify this statement, see 8.2.3 Reduces procedural errors performed by Doctors. Consider the scenario in which the software notifies a doctor of a mistake that would have otherwise led to a patient developing a serious condition such as pelvic inflammatory disease (PID). This mistake would have engendered major future costs as the patient would require extended treatment over the course of her life. However, it is impossible to find a 'present-value' of this mistake as there are too many unpredictable variables to make a valid prediction e.g. advances in medical technologies, changes in the country's economic state etc.

within the Excel document have been established to automatically revise totals, so the effects of each additional cost can be instantly viewed on a 'per medical centre' scale. The following figure shows the final agreed estimate of the costs after consultation with each member of the team.

	A	B	C
1		**Fixed Costs**	**Variable Costs (Per Annum)**
2	***Costs for each Medical Centre***		
3			
4	Training of Medical Professionals	£1,650	
5	Software Installation	£150	
6	Paying for Server Space and Database		£650
7	Cost of CA and security package		£750
8	**Total**	£1,800	£1,400
9	***Costs Spread by all Medical Centres***		
10			
11	Expansion to include more STIs	£5,500	
12	Constant Part-time Employment of Software Engineer		£15,000
13	Constant Part-time Employment of Medical Expert		£15,000
14	**Total**	£5,500	£30,000
15	***Total Cost of investment per Medical Centre for 'n' Medical Centres***		
16	'n'		
17	10	£2,350	£4,400
18	5	£2,900	£7,400
19	1	£7,300	£31,400

Figure 8.1 Screenshot of Microsoft Excel Spreadsheet showing the final agreed costs of this application

NB: Variable costs will be subject to change year on year with inflation rates but are quoted here in terms of their present value.

The figures provided are the resulting estimations from research undertaken throughout the report. Some costs have been a direct insertion from earlier conclusions, for example, the £750 quoted for 'Cost of CA and Security Package' was introduced immediately after completion of section 7.2.3 Digital certificates and 7.2.4 Conclusions of purchasing a DC. Other costs required a more creative approach to give an approximate numerical cost. For example, the cost 'Expansion to include more STIs' takes the estimated professional hours

needed to complete the package calculated in section 1.6 Expansion of pathways to include complete package of STIs in the UK and multiplies these times by a sensible hourly rate of a medical or software professional to obtain £5500[11].

All other costs have been completed in a similar vein and an entire breakdown can be found within the logbook of Liam Mawe.

From these estimations, it can be seen that $\mathbf{£5500} + \boldsymbol{n}(\mathbf{£1800})$ is required to cover total fixed-costs, where *n* is the number of medical centres deploying this application. The total variable costs will then equal $\mathbf{£30,000} + \boldsymbol{n}(\mathbf{£750})$ p.a. (present-value).

Before a final estimation of the cost of this application is given, the effects of overheads should be considered. An overhead is an accounting term which refers to the ongoing expense of operating a business that does not directly contribute to the product. Estimations of overheads are notoriously difficult to predict but should nevertheless be considered to give a more honest reflection of the required total capital injection. A typical overhead ratio (overheads:total direct costs) for a private company is approximately 25%[12]. An investor should update this percentage with an estimate using their company's typical overhead ratio.

The final estimation of capital that needs to be raised in order to complete this project is;

$$\boldsymbol{TOTAL\ FIXED\ COSTS}: [£5500 + n(£1800)] * (1 + OHR)$$

$$\boldsymbol{TOTAL\ VARIABLE\ COSTS}: [\ £30{,}000 + n(£1400)] * (1 + OHR)$$

where '*n*' is the number of medical centres deploying this application and '*OHR*' is the overhead ratio . For an estimate of the costs on a 'per medical centre' scale simply divide each of these equations by '*n*':

[11] Hourly rate of £37.50 used [30].
[12] Forbes [31] quotes %23.36 as the average overhead of private companies. 25% has been used here as this percentage is not meant to be an accurate description but rather an indicator to investors of the extra capital that would be required.

$$\boldsymbol{FIXED\ COSTS}: \left[\frac{£5500}{n} + (£1800)\right] * (1 + OHR)$$

$$\boldsymbol{VARIABLE\ COSTS}: \left[\frac{£30{,}000}{n} + (£1400)\right] * (1 + OHR)$$

The results have been arranged to make a clear distinction between costs which can be shared by multiple medical centres and those which are unique to each individual medical centre (shared costs are the terms that are inversely proportional to '*n*'). This is an important distinction and highlights the advantage of a large-scale deployment of the application. The most suited clients for this application will be medical chains with an involvement with sexual health (NHS GUM clinics, Better 2 know GUM clinics) who can install the application in several clinics at once and reduce both the fixed and variable costs per medical centre. If the decision to invest in this application is made, an appropriate marketing strategy should be aimed primarily at such chains.

8.2 Application benefits

The benefits of the application have been exposed throughout the report but will be summarised here in their most natural form (i.e. not converted into monetary terms) to be consistent with the holistic approach to comparing costs and benefits discussed earlier.

8.2.1 Reduces required nurse-time

The standard clinical procedure after being diagnosed with an STI is to first have a consultation with a nurse. The nurse then decides if standard treatment is suitable and if so, recommends the standard treatment to the doctor who then reviews the information provided by the nurse and will prescribe medicine if necessary. Alternatively if there are unusual circumstances involving the patient, the nurse will refer that patient to the doctor such that a more qualified decision can be made regarding the treatment. In both of these instances, the need for the nurse's consultation is eliminated as the application will make a similar treatment recommendation to the doctor.

This reduction in the nurse's work-load would mean that their services can be displaced into other areas of the medical centre or alternatively, the medical centre may wish to employ fewer numbers of nurses to save on costs. A reduction of one nurse in a medical centre will save between £21,478 and £27,901 p.a. (50).

8.2.2 Eliminates paper records

A system employing electronic records will be more efficient and safer than traditional methods using paper records and is supported by the following academic sources (51) (52).

8.2.3 Reduces procedural errors performed by Doctors

The application will reduce human error associated with errors in diagnosis or treatment. The questions asked by the software and the associated automated responses ensure that necessary information is obtained about the patient before decisions are made. As an example, all minors diagnosed with an STI need to be considered for sexual abuse. Without the application, it is possible that a medical professional would forget to follow these necessary procedures. Conversely, the application asks for information about the patient's age and will automatically prompt the doctor to consider sexual abuse if the patient is less than 18 thus reducing the likelihood of such a procedural error. Law-suits following procedural errors are one of the main costs for medical institutions and new technologies, like that of this application should be embraced to reduce these errors and consequent pay-outs. As a useful gauge of the magnitude of these costs, 25% of the current NHS budget is spent on law-suits due to clinical errors (53).

8.2.4 Keeps medical advice up-to-date

As there is ongoing maintenance and updates as part of the design plan, using this application assures that treatment and advice is up-to-date with the latest advancements in this area of medicine. This is more reliable than the current method of relying on doctors' own initiative or supplementary training top stay up-to-date.

8.2.5 Increases efficiency of the patient pathway

Patients are able to fill out as much information as is possible via the patient-website before arriving at the clinic, meaning time spent at the clinic is kept to a minimum. Additionally, the standardised procedure has been created to achieve maximum efficiency as the patient is thoroughly examined in the shortest possible time. For example, question-order has been carefully considered such that those questions whose answers may reduce the need to ask further questions are asked first. This saves doctors' and patients' time.

9 Project Evaluation

To evaluate the project, certain metrics cab be looked at. The goal of this project was to save time for both patient and doctor and reduce errors in drug prescription. To measure success measure the extent of this time saved. The system may reduce the staff requirements at GUM clinics and the money saved by implementing the system can be measured.

Another measurement of success is how well used the system is and what proportion of STI appointments are booked through the system.

10 Conclusion

This project has designed a system to streamline the process of diagnosing and treating sexually transmitted infections. By allowing the patient to fill out personal information and symptoms at home, the process reduces the amount of time spent in a GUM clinic. Instant Tallis diagnosis saves the doctor's time and reduces the likelihood of drug prescription error by taking into account factors such as whether the patient is pregnant.

The patient website is a responsive website which can be easily accessed from both desktop and mobile devices. It collects patient information, is simple and intuitive to use and is easy to maintain.

The doctor application is a Tallis application that uses decision logic to give preliminary diagnoses and drug recommendations for GUM clinic patients. Three medical pathways have currently been implemented and more can be added.

A third party company such as rackspace.co.uk will host the application. This gives us scalability, reliability, cost and maintenance benefits over buying and running servers independently.

The database uses MySQL to store patient information. This information can be called upon by the doctor's Tallis application for use in diagnosis. The database will be backed up and secured by the hosting company.

Security has been considered to ensure that patient information is kept secure when stored in the database and when it is being communicated to and from the database via online channels.

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