BanTeC, an image management software for corneal transplantation

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Abstract. The aim of this project was to develop a program called BanTeC (*BANco de TEjidos Corneales* – Corneal Tissue Bank). This software has been designed and developed to be used by the staff of the Tissue Bank, in the *Hospital de la Santa Creu i Sant Pau* (Barcelona, Spain). Its main objective is to provide a tool to manage all the information concerning the corneal tissues, as well as the application forms sent by other hospitals, since the Hospital is a tissue distributor at a national and an international level. This program should be considered as a support tool for CARREL.

1 Introduction

Until the date, almost all the management of the tissues of the Tissue Bank has been performed manually, using only paper support: no database nor computer tool was used to control electronic versions of the used documents and medical reports. All the information concerning a single piece of corneal tissue was then spread between folders containing hand-written evaluation reports, a computer connected to a specular microscope used to acquire and store image files, and fax tissue requests from other transplanting centres.

The main objective of the BanTeC project was then to create a computerised system to integrate and classify all the information and the documents used in the Hospital to manage all the donated and transplanted corneal tissues. The developed system carries out two important tasks: to make the control of the corneas much easier, integrating all the information into a single database system; and to create an case-based historical archive, that can be used to make statistics and studies in order to improve the quality of tissue processes. In short, BanTeC software aims to achieve the infor-

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matization of the Tissue Bank. All the stages of the development had been covered, from specification of the functionality needs of the system, the design of its architecture, the implementation of the different software components, to the total integration of the final solution in the real production environment. This is a first significant step towards the use of intelligent agents; these agents must be able to use the available information to mediate among hospitals to speed-up all the processes and support medical decisions. The design of the CARREL multi-agent system is presented in [3], [4] and [5]; this project is today being developed at the *Hospital de la Santa Creu i Sant Pau* and at the *Universitat Politècnica de Catalunya.*

2 Scenario

Firstly, it is very important to describe all the different steps of the life cycle of a cornea used for transplantation. Only if these phases are perfectly known, we shall be able to decide the functional requirements of the software application we want to specify. This section aims to give all the details of the real scenario of the Tissue Bank and enumerate each step and process that must be followed before and after corneal transplantation.

(a) EXTRACTION: when a patient dies in the hospital, he/she becomes a potential organ and tissue donor. If the hospital can get the family consent, the tissue bank doctors and the corresponding surgeon will then start the retrieval process of tissues. Concerning corneas, it is very important to act immediately, to avoid tissue damages after the death of the patient. It's then absolutely necessary to control the different time gaps between the death (asystole) and the beginning of the conservation process of the cornea tissue in a cold environment, since several processes have to take place: enucleation (extraction of the eyeball) and resection of the corneoscleral disc.

(b) DATA ANALYSIS (obtaining clinical data): once the corneal tissue is stored and preserved in the chamber (4° C), several groups of data have to be collected. These data concerns the cornea itself and the donor as well. They may give to the ophthalmologist all the necessary information in order to decide if the extracted tissue may be used for transplantation or not. Different kinds of tests must be done:

· Donor serology: several parameters are here necessary to evaluate an hypothetical transplantation: blood group, Rh, absence of antibodies against different viral diseases (mainly AIDS and Hepatitis B and C). A sample of the tissue is sent to the laboratory to be cultured to discard fungus or bacterial infections.
· Biomicroscopy: the tissue is observed using a split lamp that gives the doctor a macroscopic perspective of the analysed cornea in order to check that there is not any important damage nor any undesirable characteristic in it.
· Microscopy: a specular microscope is used to analyse the cornea; this device generates a string of images that allows the specialist to find the endothelial cell

count and its size and variation. The doctor can, in short, decide the quality of the extracted corneas.

(c) EVALUATION: using all the collected information in the previous step, the doctor of the Tissue Bank can generate a report to evaluate the cornea. This report must decide if the tissue is suitable for being used for transplantation and then implanted in a recipient or, otherwise, if it must be discarded.

· If the quality of the tissue is good enough and it can be used for transplantation, it can be preserved at 4°C for a week, waiting for a recipient to request it. The cornea may then be allocated and transplanted if such a recipient is compatible and matches some necessary parameters. After 7 days, the tissue is no longer valid and cannot be used anymore.
· If the cornea is not suitable for transplantation, it normally can be used for study or academic purposes.

(d) REQUEST: the Tissue Bank of the *Hospital de la Santa Creu i Sant Pau* is a national and international tissue distributor. Other hospitals send tissue requests using telephone and fax machines. These request must hold all the information about the destination hospital, the personal information and data of the recipient and any other relevant information concerning the need of a transplantation (diagnosis, data of the operation, ophthalmologist that is going to perform the transplantation and so on). If there is not urgent needs, the requests are fulfilled in chronological order (of course, a possible recipient must match some clinical parameters).

(e) ALLOCATION: once there is several available and valid cornea in refrigerator of the Tissue Bank and several unfulfilled tissue requests, the doctors of the Hospital de Sant Pau must try to allocate each cornea to the most appropriate recipient, according to compatibility rules. When a tissue is finally allocated to a request, the doctor of the Tissue Bank sends by fax the evaluation report to the destination hospital, where the surgeon that is going to perform the transplantation must accept the tissue. If so, the Tissue Bank must plan the transport of the piece and send also a bill reflecting its cost (procurement, preservation, quality control and distribution) to the destination hospital.

(f) CONTROL: when a hospital receives a cornea for transplantation from the Tissue Bank of the Hospital de Sant Pau, it undertakes to send back a information report after three weeks. That report must reflect the state of the transplantation: successful implant, eventual infections, primary rejection and so on.

(g) ARCHIVE: the Tissue Bank must always keep all the information and reports about extracted, distributed and transplanted cornea tissues. Even if a cornea is not suitable, all the documents concerning it must be stored. Only doing so, the Tissue Bank can eventually generate statistic reports about its activity, analyse them and use the results to improve the performance of its processes. Further-

more, all the generated information and images about corneas can be used with academic or study purposes.

3 Objectives

The used documents and reports, and the workflow processes described in the previous section are the main threads of the specification of the developed BanTeC application. The main objective of the project was to reflect and reproduce the scenario, described above, using essentially the same information that the Tissue Bank worked with. The aim of this section is to give a first approach of the most important requirements and features of the developed software system: which information is managed by the application, how it is shown, which operations can be performed with it and so on. The main functionalities of the system are listed next.

(a) Management (add/delete/edit) of all the information concerning donated corneas and tissues. That includes data about tissue registration (identification code), donor personal information (name, age, cause of death, other diagnosis), extraction data (exitus, enucleation and resection date and time, extractor ophthalmologist), donor blood group and Rh, donor serology results (HIV, HBV and HCV), bitmap images acquired using the specular microscope, microscopy (cellular density and size, variation rate, pachimetry) and biomicroscopy (eventual damages and/or structural injuries) results. Using all the previous information, the application must allow the doctor to validate (suitable for transplantation) / invalidate (not suitable for transplantation) the cornea.

(b) Management (add/delete/edit) of the information about received tissue requests. This information concerns destination hospital data (name, address, telephone and fax number, contact person), recipient personal data (name, age, blood group and RH, diagnosis, medical record) and any other relevant information about the request (date, transplantator ophthalmologist, planned date of the operation, urgent need and so on). The system allows the doctors of the Tissue Bank to allocate a valid cornea into a recipient waiting for it. When that operation is performed, the system generates automatically a bill that the Tissue Bank will send to the destination hospital.

(c) Management (add/delete/edit) of the control reports, generated three week after the transplantation. These reports contain the following data: date of the inform, doctor, success/rejection, eventual infection and text comments.

(d) Implementation of a case-based image archive (image bank): the system database stores all the images generated by the specular microscope in order to allow doctors to study and compare particular cases.

(e) The processes and operations that can be applied to each cornea in the system depends on its state, according to the norms and protocols of the *Hospital de la Santa Creu and Sant Pau.*

(f) The system is able to generate electronic and paper (prints) versions of each kind of document and report previously used by the Tissue Bank. The impact of the integration of the software application was then reduced, since BanTeC adapted the previous workflow of each cornea.

(g) Implementation of a graphic editor of biomicroscopy diagrams. This editor allows the evaluator to create, annotate and edit images to represent the observations made using the split lamp in order to illustrate text annotations and cornea description.

The BanTeC application design had another secondary objectives that must be mentioned as well. These objectives are non-functional requirements, but had to be satisfied in order to guarantee the success of the project.

(h) The graphic user interface (GUI) must be as easy to use as possible, since the end-users are not usually computer or informatics experts, but doctors. It is then essential to implement a user-friendly interface: only this way, the experts in medicine will find the application attractive and use it.

Going on with the same idea, BanTeC includes an integrated help system. The aim of it is to assist the user with the main operations. The way to achieve this objective is to use very detailed and step-by-step explanations, screen shots and contextual help.

4 Used technologies

The aim of this section is to justify all the technologies used to develop the BanTeC project. Next, a list of such technologies is presented.

(a) The first design decision was to use a *wintel* platform to use and develop the project. Such a decision has a lot to do with the user-friendly interface mentioned above, since almost every single user in the hospital is familiar with Microsoft Windows and the way the applications works.

(b) Microsoft Access 97 and Microsoft Jet 3.5 engine was used at database level, since the amount of data managed by the application (300-400 donors, recipients, transplantations a year) does not require a more sophisticated and more expensive database engine. Microsoft Access 97 is the most commonly used database in the *Hospital de Sant Pau* and it is installed in almost every computer running under Windows.

(c) DAO 3.5 (Data Access Objects) was the chosen data access technology, since its efficiency is optimised to use together with the Jet engine.

(d) Microsoft Visual Studio and Visual C++ were the used environment and programming language to carry BanTeC out. Visual Studio offers the MFC (Microsoft Foundation Classes) to the developer. The MFC include DAO derived classes and are suitable to create Windows desktop applications.

The corneal images are stored and displayed using the bitmap (BMP) format, since the specular microscope generates them this way. The main advantage of it is that any quality loss is avoided; no color is used in those images, so the used disk space is reduced.

5 Limitations and future work

As said in previous sections, the BanTeC main objective is to help the Tissue Bank doctors in the management of all the corneas information, but this software system does not take any decisions nor any responsibilities. The aim of the system is to reflect and integrate all the information previously introduced by the staff and the doctors of the Tissue Bank.

First, the application cannot decide if a cornea is suitable or not for transplantation; this decision corresponds only to the doctors or to the responsible of the Tissue Bank. BanTeC cannot decide when a cornea is no longer valid for transplantation either, after a week of preservation: if the doctor finds it appropriate, the cornea could be allocated into a recipient. Finally, the software application will not decide how to allocate available tissues (BanTeC will not match donors and recipients); the application will not decide the order the requests are fulfilled either. All these responsibilities concern the doctors exclusively: BanTeC only will reflect the information and the state of the corneas of the Bank but the application will not act in consequence.

The previous limitations suggest an obvious line of future work. The idea is to design a multi-agent intelligent system to assist the doctors in cornea allocation process: this system will need to match parameters from the donor and the recipient (ages, serologies, histocompatibility...) and the tissue itself (cellular density and size, period of preservation). Another different line of development is to extend the system to manage different kinds of organs and tissues, since the scenario is analogue and very similar to the corneas scenario described in this article. The aim of the CARREL project ([3], [4], [5]) is to create a virtual organization for the procurement of organs and tissues for transplantation purposes.

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