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Tissue and corneal donation and transplantation in the UK

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Editor's key points

- Tissue and cornea transplantation can be life enhancing and occasionally life saving.
- The selection criteria for tissue and cornea donation are more stringent than for solid organs.
- Eyes retrieved from multi-organ donors have increased usability to those retrieved from tissue-only donors.

Summary. NHS Blood and Transplant (NHSBT) was established in 2005 as a Special Health Authority when the National Blood Authority and UK Transplant merged. This helped to bring tissue banking and organ transplantation services under one umbrella organization. This merger means that ~95% of all deceased donors (whether tissue, organ or both) are now facilitated by one organization. NHSBT Tissue Services is the largest tissue establishment in the UK, and is a multi-tissue bank that specializes in the consent, retrieval, processing, storage, and dispatch of donated tissue coordinated from a purpose built, state-of-the-art tissue bank in Liverpool. Tissue donations can come from either tissue-only donors or solid organ donors who also donate tissue. Annually there are ~450 multi-tissue donors and 2500 eye donors in the UK, resulting in many thousands of transplants, including 3564 cornea transplants in 2010–2011. The separation of tissue- and organ-specific donors is largely artificial, and while organ transplantation can be life-saving, tissue transplantation can also have a dramatic effect on a patient's quality of life. It is hoped that all donors, both organ and tissue, will be recognized for the gift they make to society after their death.

Keywords: allograft; corneal transplantation; tissue and organ procurement; tissue banks; transplantation

Tissue transplantation has a dramatic effect on a patient's quality of life and occurs on a somewhat larger scale than organ transplantation. In the UK, there are ~450 multi-tissue donors and 2500 eye donors every year, resulting in many thousands of transplants, including 3564 cornea transplants in 2010–2011. Some types of transplants, such as cornea and heart valve transplantation, have been established for many decades and are reasonably well understood by health professionals. Other types of tissue donation, such as bone, skin, tendons, etc., are much less well known but nonetheless result in beneficial, and occasionally life-saving, treatments for patients.

History of tissue and eye banking in the UK

In 1992, the fragmented, unregulated, and local nature of bone banks was described by the British Orthopaedic Association as a 'cottage industry'.[1 2] This description could equally have been used to describe tissue banking generally. Tissue banks tended to concentrate on one particular tissue relevant to the interested surgeon who had established them (e.g. femoral head banks, skin banks, and eye banks) and there was no legislation pertaining to their regulation. The Yorkshire Regional Tissue Bank was the first multi-tissue bank in the UK, and dates back to 1955. It was established by the then Yorkshire Regional Health Authority to provide the Yorkshire region with skin, bone, and heart valves. The North Wales and Oswestry Tissue Bank was established in 1991, while there were also skin banks based in Sheffield and London.

The National Blood Service (NBS) (now part of NHS Blood and Transplant) became involved in tissue banking after recommendations issued by the Department of Health, whilst the Corneal Transplant Service (CTS) was established in 1983 by the former UK Transplant Service (now NHSBT). The strategy within NBS was to both rationalize and centralize tissue banking into the purpose built, state-of-the-art Tissue Bank in Liverpool which opened in 2005. This brought most aspects of tissue banking, except for eye banking, under a single management structure. This national facility is supplemented by four eye banks and five further heart valve banks. The four eye banks are housed in NHS Trusts; two are CTS eye banks (Bristol and Manchester) funded via NHSBT, whilst those in Moorfields and East Grinstead are funded by their own Trusts. These respective eye banks issue corneas to the corneal transplant centres.

NHS Blood and Transplant (NHSBT) was established in 2005 as a Special Health Authority when the National Blood Authority and UK Transplant merged. This helped to bring tissue banking and organ transplantation services

Table 1 List of tissues donated and transplanted and their applications

Tissue donated	Type of product	Clinical application
Skin from the legs and back	Cryopreserved skin (disinfected with antimicrobials and cryopreserved)	Treatment of major burn injury
Bone (femurs/ knees)	Ground bone/shaped implants (washed, freeze dried, or frozen and irradiated)	Orthopaedic and spinal surgery
Heart	Aortic/pulmonary heart valve (disinfected with antimicrobials then cryopreserved)	Cardiovascular surgery (valve replacement)
Tendons	Patella tendons, achilles tendons, semi-tendonosis tendons (dissected, decontaminated)	Orthopaedic surgery, sport injury
Eyes	Cornea, limbus, sclera	Corneal transplantation, stem cell transplants, glaucoma surgery

under one umbrella organization, and means that approximately 95% of all UK deceased donors (whether tissue or organ or both) are now facilitated by one organization. NHSBT Tissue Services is the largest tissue establishment in the UK; it is a multi-tissue bank, which specializes in the consent, retrieval, processing, storage, and dispatch of donated tissue. Tissue donations can come from either tissue-only donors (e.g. eye-only donors), multi-tissue donors (e.g. eye, bone, and skin donors), or solid organ and tissue donors. Tissues that can be donated are listed in Table 1, which also includes the resulting products and how these can be used in recipients.

Tissue and eye donation

The pathway of tissue and eye donation and subsequent transplantation in the UK consists of the following five main stages.

Identification and referral of the potential donor

Unlike organ donation, tissue can be retrieved many hours after death has taken place, meaning that the potential pool of tissue donors is far greater than that of solid organ donors. However, the selection criteria for eye and tissue donors are much more stringent, because of the rather different balance between the benefits and risks of tissue grafting when compared with organ transplantation (current Tissue Donor Selection Guidelines are available at http://www.transfusionguidelines.org.uk). In the majority of cases, an organ transplant is a life-saving/-extending procedure and whilst this can also be applied to some tissue transplants (e.g. where skin is used in the treatment of major burns or in the case of a heart valve transplanted into a child), in the majority of cases, tissue is used to improve the quality of life. Furthermore, although a tissue allograft might be the preferred treatment, alternative treatments/ implants may be available. For example, the most transplanted tissue is bone and is used to improve the clinical success of a range of orthopaedic operations such as joint replacements, spinal fusion, and reconstructive surgery. In these cases, although the benefit is significant, it is life-enhancing and must be associated with an extremely low risk of disease transmission to justify its use. The same applies to cornea transplantation. The rationale for such a stringent approach to tissue donor selection is strengthened by the fact that there may be as many as 50 different recipients from a single tissue donor, thereby amplifying the consequences of any disease transmission.

Consent (authorization in Scotland) and medical assessment of the donor

Tissues are much more resistant to the effects of ischaemia than solid organs, and this allows a rather more comprehensive and less hurried assessment of the suitability and risk status of the potential tissue donor to be made. Tissue can also be stored for long periods of time, which means that extra information regarding the donor can be collected and assessed centrally before transplantation. This differs considerably from organ transplantation where it is the transplanting team who decide whether to use an organ or not. The primary source of medical and behavioural history is the donor's family or close friends, and the information is gathered through a structured interview that is conducted most frequently by telephone. Thus, although medical and behavioural history may be recorded in the patient's hospital notes, it is always supplemented by discussion with the family or life partner of the potential donor. It is important to establish who knew the donor best and who can provide the most detailed information, and may necessitate interviews with more than one individual. However, it is the person in the highest qualifying relationship with the deceased who will give the appropriate consent.[3] The type of tissue donated by each donor is dictated by the age and cause of death of the donor. However, skin, eyes, and bone do not have an upper age limit and therefore access to transplantation is not necessarily limited by potential donor numbers.

NHSBT receives >6000 potential deceased tissue donor referrals per year via the Tissue Services National Referral Centre (NRC) in Liverpool. The NRC is staffed by trained nurses who manage these referrals, obtain consent, take a medical and behavioural history, and organize the retrieval. A deceased tissue donor can ordinarily donate eyes, skin, bone, tendons, and heart valves. Because of the tissue processing and dispatch functions of Tissue Services being under the same management as the consent aspects, there is an efficient feedback mechanism to ensure that consent is only obtained and tissue collected in response to patient and surgeon requirements. In 2010, there were >400 multi-tissue donors and 1200 eye-only donors

facilitated by the NRC. Specialist Nurses for Organ Donation working in acute hospitals also obtain consent for tissue retrieval from solid organ donors, with a high proportion of heart valves coming from organ donors where the heart itself is unsuitable for organ transplantation.

Tissue and eye retrieval

Tissue and eye retrievals are usually performed in a hospital's mortuary by trained professionals. Eye retrieval follows the guidelines of the Ocular Tissue Advisory Group of NHSBT and The Royal College of Ophthalmologists, ensuring that the tissue is retrieved in the best possible condition while respect for the donor is maintained at all times. After retrieval, a prosthesis is used to rebuild the orbital shape and restore the donor to their former appearance. Eyes should be retrieved as soon as possible after death, preferably within 12 h and no longer than 24 h post-mortem.[4 5] This is to help reduce the accumulation of a microbial load on the ocular surface that occurs post-mortem because of the lack of tears and blinking, and reducing the build up of metabolic waste products in the aqueous humour that can lead to increased endothelial cell loss.[6]

Other tissue such as bone or skin may be suitable for retrieval up to 48 h post-mortem.[4] NHSBT has three tissue donation departments based at Leeds, Liverpool, and London. There are six tissue donation teams available at any one time to perform a tissue retrieval in a hospital mortuary. The teams routinely travel a maximum of 2 h or 100 miles from their base. The donor is prepared as if undergoing a surgical procedure in an operating theatre before the retrieval and is reconstructed afterwards to their normal appearance.

Tissue and eye processing and storage

Once the respective tissue and eyes have been retrieved, they are transported to the tissue or eye bank. Skin and hearts are processed immediately on receipt at the tissue bank to conserve the structure of the tissue. The skin and heart valves are disinfected in an antimicrobial cocktail overnight before packaging and cryoprotection in the vapour phase of liquid nitrogen. Samples of the tissue are taken before and after disinfection to ensure that the final tissue product is suitable for transplantation. Bone and tendons are frozen at $-80^{\circ}C$ until authorization that the donor tissue is clinically acceptable has been received. Deceased donor bone is shaped into the required bone grafts which are then put through a complex series of washes to remove cell debris, blood, and marrow. Retrieved eyes are sent to the UK eye banks from hospitals across the country for assessment and preparation, with the corneoscleral disc being placed in organ culture for up to 4 weeks before transplantation.

Stem cell technologies offer an exciting new avenue for tissue transplantation. The next generation of tissue grafts, for example, the trachea, will result from a composite of a scaffold of human origin with autologous stem cells reseeded and grown in a bioreactor before transplantation.

Tissue and cornea transplantation

Despite a large potential donor pool in the UK, there exists a shortage of eye donors. For example, the estimated number of corneas needed for transplantation is ~5000 per year, leaving a current shortfall of 1500. As a consequence, the quality of life for many patients is significantly impaired, (e.g. the number of people registered blind or visually impaired in England is 147 800 and 151 000, respectively).[7] Even a relatively small reduction in vision may have a profound effect on a person's ability to meet the needs of their work environment or driving standards. Corneas are issued to >200 cornea transplant units across the country and NHSBT holds a statutory responsibility for the monitoring and analysis of transplantation outcomes and related adverse events and reactions.

It is difficult to assess demand for other tissue as the supply has been relatively uncoordinated in the UK. NHSBT are the only UK suppliers of skin and processed bone although similar tissue products can be imported from the USA and Europe. There are no waiting lists held for tissue in the UK, although whether this represents a surplus of supply or the choice of alternative surgical solutions (e.g. use of a prosthetic heart valve rather than an allograft) is unclear. All the UK heart valve banks now collaborate under a single 'National Fulfilment System' in order to manage all requests for heart valves, record any unmet demand, and allow the service to be planned in the future.

Corneal transplantation in the UK

The first successful corneal transplant was performed more than 100 yr ago in 1905.[8] Today, corneal transplants are one of the most common transplant procedures. Between 1998 and 2007, an average of 3684 corneas were donated each year in the UK, of which 2320 (63%) were suitable for transplantation, with more than 90% of recipients having a clear functioning transplant at 1 yr. The remaining 37% of donated corneas were unsuitable for transplantation due mainly to medical contraindications to transplantation or an insufficient endothelial cell count. Donor age has a considerable impact on the quality (and therefore usability) of the donated corneal tissue, and it is of concern that in the UK the median age of eye-only donors is 70–80 yr when compared with the USA where the average donor age is 40–50 yr.[9]

The ocular tissues which are currently transplanted after eye donation are the cornea, the sclera, and the limbus (the junction between the cornea and conjunctiva containing the corneal epithelial stem cells). The cornea is ~12 mm in diameter, 0.5–1 mm thick, and is composed of three main layers: an anterior multi-layered epithelium, the stroma (composed mostly of collagen fibres and proteoglycans), and a posterior monolayer of endothelium. The curvature and transparency of the cornea enable it to fulfil its principal function of focusing light. The transparency of the cornea is attributed to lattice arrangement of the collagen fibres in the stroma, which is easily disrupted by trauma, infection, or oedema from failure of the endothelium. There are

Table 2 Indications for corneal transplantation; first grafts from 1 April 2008 to 31 March 2011

Indication	*n*	%
Shape (Keratoconus)	1405	27.4
Endothelial failure (Fuchs' dystrophy)	1326	25.8
Endothelial failure (post-cataract surgery)	1076	21.0
Infection	489	9.5
Injury	121	2.4
Ulcerative keratitis	134	2.6
Opacification	219	4.3
Other	360	7.0
Total	5130	

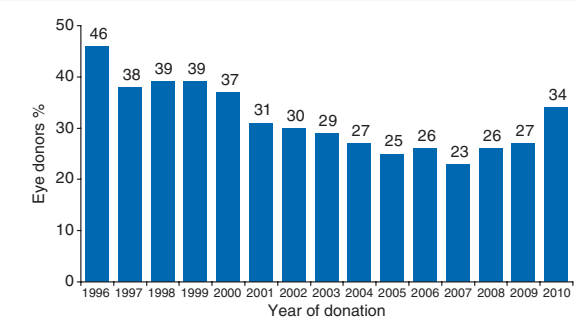

Fig 1 Percentage of eyes procured from solid organ donors, 1996–2010. In 1996, 46% of solid organ donors were also eye donors. The donation rate decreased to 23% in 2007 but has since increased to 34% after EPSOD was established to monitor the rate of eye donation from solid organ donors. These data include those donors who were medically unsuitable (data not available before April 2008 since it is collected in EPSOD datasets).

many indications for corneal transplantation, some of which are grouped together under the headings listed in Table 2. The improvement of vision after corneal transplantation can be dramatic. A person whose best visual acuity is <3/60 (able to see at 3 m what a normally sighted person would see at 60 m) is considered to be blind. The improvement in visual acuity after corneal transplantation is from a median of 6/60 to a median of 6/12. This leads to a dramatic improvement in a patient's quality of life, economic opportunities, and independence.[10]

The organization of eye donation and retrieval in the UK has improved considerably in recent years. The Ocular Tissue Advisory Group of NHSBT, made up of representatives of ophthalmologists from each region in the UK, the eye banks, and other interested parties such as the Royal College of Ophthalmologists, provide formal advice and guidance to NHSBT regarding standards for ocular tissue donation and transplantation in the UK and the development of safe and equitable selection and allocation criteria. The Eye Retrieval Scheme (ERS) was an initiative put forward by this group, and has the strategic objective of providing 3500 corneas per year with 70% usability for transplantation. The ERS have designated teams in selected Trusts/Health Boards whose roles include the promotion of eye donation, education and training of clinical staff, approaching the families of potential eye donors and performing the retrieval of ocular tissue itself. This has improved the number and quality of eye donations, and supports a better governance overview. The scheme currently supports 10 teams that retrieve 55–65% of eyes in the UK.

Although the majority of eyes are retrieved from eye-only donors in the mortuary, eye donations from solid organ donors are particularly beneficial because the donors are younger, the time from death to enucleation may be shorter and the retrieval can be performed in a more sterile theatre environment. It is therefore recommended that eyes from multi-organ donors should be retrieved in theatre at the same time as organ donation.[5] There has been a steady reduction in eyes donated from consented solid organ donors over the past 10 yr in the UK, and this is reflected in the increase in the donor age over this time period. The establishment of a specialist group to promote eyes from potential solid organ donors (EPSOD) has however reversed this trend, with eye donation from solid organ donors increasing from 29% of medically suitable organ donors between April and December 2008 to 41% between September 2010 and March 2011 (Fig. 1). The principal reasons for failure to retrieve eye tissue from consented solid organ donors are family refusal (variously attributable to a known wish of the deceased, fears regarding external disfigurement, and religious/cultural objections), medical contra-indications (reflecting the more stringent rules for eye and tissue when compared with organ donation) and objections from the coroner or procurator fiscal.

Conclusions

The separation of tissue- and organ-specific donors is largely artificial, and it is hoped that all donors will be recognized for the gift that they make to society. The creation of NHSBT has brought organ and tissue donation together, and further collaboration and integration will lead to a more efficient service that will be better placed to lead and sponsor future innovation and development.

Declaration of interests

S.B.K. is Chair of the Ocular Tissue Advisory Group (OTAG) to NHS Blood and Transplant (NHSBT). L.G. is eye retriever representative on OTAG and eye retrieval coordinator at the Royal Liverpool University Hospital. I.R. is Donation Manager for the Eye Retrieval Scheme at NHSBT. A.J.C. is Assistant Director for Organ Donation at NHSBT, professional lead for the Eye Retrieval Scheme and a member of OTAG. M.N.A.J. is statistician at NHS Blood and Transplant with specific interest in corneal transplantation and analysing data from the UK Ocular Tissue Transplant Audit. H.L.G. is Head of Operations at NHSBT Tissue Services, Chair of the OTAG Sub-Group for

Allocation of Corneas and Executive Committee member of the British Association for Tissue Banking.

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