Umbilical cord blood banking: economic and therapeutic challenges

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Abstract: Since the first successful transplantation of umbilical cord blood in 1987, cord blood has become an important source of haematopoietic stem cells for the treatment of blood and genetic disorders. Important progress has been accompanied by challenges for scientists, ethicists and health policy-makers. With the increasing focus on cord blood as an alternative to human embryos and as a source of tissue for regenerative medicine, umbilical cord blood stem cells have attracted significant attention. In this paper, we review the therapeutic challenges and the competition between private and public cord blood banks, and also between cord blood inventories and bone marrow registries. We provide an international overview of banking activities, with a special focus on the French paradox. From access to bioresources to patent controversies, we analyse the economic impact of cord blood banking on health policies, and then discuss some ethical dilemmas of stem cell research.

Keywords: banking; bioethics; bone marrow; cell therapy; cord blood; health policy; regenerative medicine; stem cell, transplantation.

Reference to this paper should be made as follows: Katz-Benichou, G. (2007) 'Umbilical cord blood banking: economic and therapeutic challenges', *Int. J. Healthcare Technology and Management*, Vol. 8, No. 5, pp.464–477.

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1 Introduction

Recent breakthroughs in cord blood stem cell research cast a new light on the clinical and ethical debate over regenerative medicine. Stated several ways, the same recurring question is raised: is there an alternative source of pluripotent stem cells for tissue engineering that does not require the use of human embryos or therapeutic cloning? Current sources of stem cells include embryonic stem cells and adult stem cells. However, concerns exist with either source: embryonic stem cells, with their ethical considerations, tumorigenicity; and adult stem cells, which are possibly more limited in potential. Beyond this dilemma, umbilical cord blood stem cells may delineate a concrete alternative solution, and provide an ethically uncontroversial and easily accessible source of pluripotent cells for future experimental and clinical applications.

2 Therapeutic challenges

In 1987, umbilical cord blood (UCB) hematopoietic stem cells from a related sibling were transplanted successfully into a five-year-old child with Fanconi anaemia by Eliane Gluckman and colleagues (Gluckman et al., 1989). Subsequently, over 7,000 UCB transplantation procedures have been performed worldwide using UCB from related and unrelated donors into paediatric (Locatelli et al., 2003; Rocha et al., 2000; Wagner et al., 2002), and adult patients (Gluckman et al., 1997; Rocha et al., 2004). UCB offers many advantages, ranging from easy procurement, no risk to donors, reduced risk of transmitting infections, immediate availability of cryopreserved units, and acceptable partial HLA mismatches. Furthermore, the incidence of graft-versus-host disease (GVHD) after a cord blood transplantation is ten-fold lower than that seen after transplantation with HLA-matched bone marrow obtained from a sibling. To date, no malignant transformation of infused UCB has been observed in any transplant recipient. Nearly all patients can find at least one potential 4-of-6 HLA-matched UCB unit through Netcord, NMDP Registry, or other banks.

Reported survival rates are similar to those seen in patients transplanted with matched bone marrow from unrelated donors, despite the fact that cord blood was generally mismatched at 1 or 2 HLA loci (Barker et al., 2001). Furthermore, pilot trials combining two cord blood units for a single patient also look promising (Barker et al., 2005). Frozen UCB can be easily shipped and thawed for use when needed, compared to freshly donated bone marrow, which has a limited shelf-life, necessitating coordination between harvesting physicians, transportation personnel and transplantation teams. There is an undistorted accumulation of HLA genotypes acquired in a UCB bank, because stored units suffer no attrition except by clinical use, unlike volunteer unrelated adult donor registries, in which donors are lost due to advancing age, new medical conditions or geographic relocation.

The major obstacles to the success of unrelated cord blood transplantation today include slower engraftment times resulting in longer hospitalisations, lack of sufficient numbers of larger units containing enough cells for transplantation in an adult, and an increasing need for ethnic diversity among donors to achieve closer HLA matching.

3 Potential application in regenerative medicine

Umbilical cord blood transplantations are indicated for pediatric genetic, hematologic, immunologic, metabolic and oncologic disorders (malignancies, bone marrow failures, hemoglobinopathies, immunodeficiencies, inborn errors of metabolism). Beyond these indications, UCB cells may have many potential therapeutic applications in the field of regenerative medicine. Under appropriate induction conditions, these cells can differentiate into bone, cartilage and fat. Surprisingly, these cells are also able to differentiate into neuroglial- and hepatocyte-like cells and thus, they may be more than mesenchymal stem cells, as evidenced by their ability to differentiate into cell types of all three germ layers (Lee et al., 2004). Qualified as 'pluripotent' (McGuckin et al., 2005; Zhao et al., 2006), umbilical cord blood stem cells have also demonstrated their ability to differentiate into erythrocytes (Giarratana et al., 2005), skeletal myocytes (Gang et al., 2004), osteoblasts (Goodwin et al., 2001), chondroblasts, adipocytes, hepatocytes (Kakinuma et al., 2003), cardiomyocytes (Kögler et al., 2004) and neural cells (Lu et al., 2003) in homogeneous fashion, without cell fusion, in various animal models.

These results foreshadow new therapeutic applications ranging from liver cirrhosis, myocardial infarction and vasculopathies (Buyung-Ok et al., 2005), to brain injuries (Sanberg et al., 2005) and many other muscular (Kong et al., 2004) or neurodegenerative disorders (Garbuzova-Davies et al., 2003; Sporta et al., 2003). More importantly, unlike embryonic stem cells, the engraftment of cord blood stem cells in various species has, thus far, not induced tumours, months or even years after transplantation. Beyond the challenges of plasticity, cord blood stem cells have been expanded up to 10^{15} without losing their pluripotency (Marshall et al., 2003). These observations raise the possibility that 'umbilical cord blood may serve as a universal allogeneic stem cell source for the future development of cellular therapy and tissue regeneration' (Kögler et al., 2004).

4 Cord blood inventories and bone marrow registries

Since 1987, the clinical benefits of UCB transplantations have steadily improved. For the first time, in 2004 the number of UCB transplantations performed in Japan exceeded the number of marrow transplantations. Cord blood is no longer just an option for patients who have no other choice. As experience has increased, cord blood is becoming competitive with bone marrow as a source of haematopoietic stem cells for one and the same patient. Patients and their physicians now have two options to choose from, not just a first choice and a last resort. Indeed, UCB grafts can be found in virtually 100% of all cases for both adults and children. As of today, grafts from marrow donor files are only fully compatible in roughly 35% of all cases. In 2002, the US National Marrow Donor Program (NMDP) estimated that 'one third of patients in need search the registry, and about one tenth (9%) receive transplants' (US General Accounting Office (GAO), 2002).

Several Transplantation Center physicians now choose cord blood grafts over bone marrow or peripheral blood, even for adults. As a consequence, cord blood banks and marrow donor registries have understandably and unavoidably become competing organizations. It is even plausible that cord blood could eventually replace bone marrow as the haematopoietic stem cell source of choice in unrelated

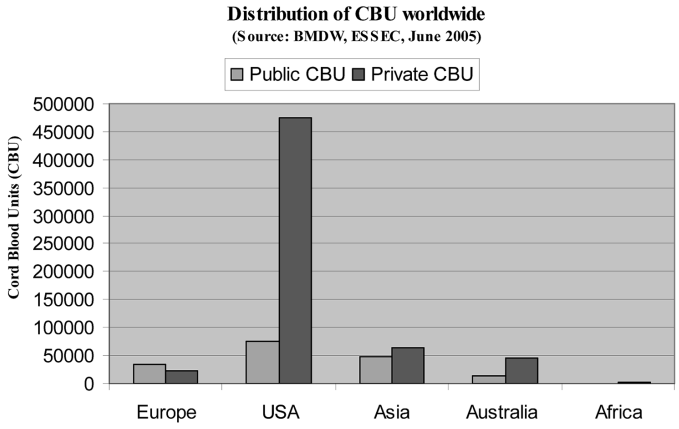
transplantations. The marrow donor registry concept may be threatened by the success of cord blood banking and vice versa. On the other hand, competition might actually work to improve performance of both organisations, to the benefit of all patients. Beyond this competition, transplantation physicians desire single point access to both available cord blood units and potential bone marrow donors. This can be accomplished if the cord blood bank network and marrow donor registries collaborate in creating a common website for the submission of search requests.

5 Competition between public and private banks

Cord blood transplantation has been made possible in large part by the creation of worldwide umbilical cord blood banks. There are two types of cord blood banks, public and private. Unrelated-donor transplantation programmes employ public banks as their source of donor cord blood units (CBU). These CBUs are donated on a voluntary basis by women delivering healthy babies at term. Private banks, which are for-profit entities, store directed donations collected by obstetricians from babies born into families who intend to use the cord blood for the baby from whom it came (autologous donation) or for another family member in need of future transplantation therapy (family donation). Policy makers suspect that private banks are taking out of circulation cord blood units which might otherwise be used for unrelated recipients. It is not clear that this is the case, since public banks restrict their collection to a local network of hospitals and it is difficult for women outside their target population to donate. Private banks have no such restrictions. But a recent study found that women in antenatal clinics had very little knowledge about cord blood banking, although 86% of those questioned would have been willing to donate altruistically; 14% would have elected to bank privately (Fernandez et al., 2003).

In April 2005, there were 77 private banks worldwide, accounting for some 620,000 cord blood units. By that time, Africa was completely dependent on cord blood resources from other continents. In April 2006, there were 134 private banks accounting for some 780,000 units (source: ESSEC, 2006). This same year, 54 public banks own a stock that is roughly one third that size: 227,000 units (source: BMDW, April 2006). See Figure 1.

Figure 1 Distribution of CBU worldwide



6 Hybrid models

Private banking is growing fast in many small countries, with uneven quality standards, and nobody knows how many of those private units are actually usable for a safe and efficient transplantation. In the US, the biggest banks are Cord Blood Registry, Cryo-Cell and Viacord: their growth rates (stored units) from 2003 to 2004 were between 59 and 83%. By July 2006, Cord Blood Registry was claiming 400,000 units in storage, with over 120,000 newborns (Cord Blood Registry, 2005). Some banks have developed a hybrid model based on a for-profit and not-for-profit banking. The most visible example of a combined public/private bank is Stemcyte: implanted both in the US and Taiwan, they operate a public bank under the name Stemcyte which is a participating member of the National Marrow Donor Program (NMDP). Under the name 'Stemcyte family' (formerly 'Cord Blood Family Trust'), they operate a private bank. Because African and Asian profiles remain under-represented in public inventories, some private banks aim at developing their inventories with these specific HLA-profiles. The largest public/private South Korean cord blood bank, Histostem, wants to bank 400,000 UCB units by 2010.

Created in February 2007 by Richard Branson, the Virgin Health Bank offers the choice of dual banking – storing the baby's cord blood stem cells, both privately and publicly – therefore potentially helping to protect a family, as well as others. At Virgin Health Bank, the cord blood stem cells are divided into two units and stored cryogenically: 20% of the original volume is reserved for directed transplantations (autologous or familial) and 80% is reserved for undirected donations (allogeneic). The chance of an autologous transplantation is extremely slim. This unit will, however, provide the family with a source of stem cells that could be used for regenerative medicine in the future. Virgin Health Bank underlines that "whilst there is research that seems promising, it would be irresponsible for us to suggest that this research is guaranteed to become a reality". In practice, cell expansion technology is likely to be required to provide a usable number of cells for regenerative medicine regardless of how many are in the original unit collected.

The other unit will be placed in the public bank for allogeneic transplantations to treat blood disorders today and other diseases in the future. By contributing to the development of public banking through private storage, hybrid banks are helping to increase the number of stem cell units and the likelihood of a matched unit for an individual, a family and others. Interestingly, private banking finances public banking and makes its economic development financially sustainable. From an ethical standpoint, this hybrid model converts exclusive bioresources into a mutualised health system accessible for an entire population. With stringent quality standards, this hybrid model could represent a point of equilibrium between private demands and public health needs.

7 Supply and demand

While private bank expansion is accelerating exponentially, the growth of public banks is constrained by public funding. In economic terms, the stock of private banks represents the demand of parents who are willing to pay for a service, whereas

the public bank stock represents a supply of care services available to a given population. Since some 78% of the cord blood units stored worldwide are held by private banks in 2006, the imbalance between supply and demand could lead public banks to become dependent on private bank inventories and pricing policies. While private banks are prohibited in some European countries, such as France and Italy, they are developing quickly in Belgium, Great Britain and Germany, and even faster in Asia and the USA.

As commercial cord blood banking has proliferated, its ethical justification has been widely debated (Annas, 1999; Burgio et al., 2003; Ecker and Greene, 2005; Fisk et al., 2005). Generally, an initial storage fee of $1300–2000 is charged followed by a yearly storage fee of approximately $100. Private banks are regularly accused of selling false therapeutic promises to parents, operating with inadequate storage conditions, and creating discrimination between patients through the money factor (The European Group on Ethics in Science, 2004). Many private banks advertise their services, promising, for example, 'peace of mind and a powerful medical resource used to treat many severe illnesses for your child and loved ones' (Cord Blood Registry, 2005). This debate has been reopened after the report of successful autologous cord blood transplantation in the treatment of a child with leukemia. At birth, the parents decided to store the newborn's umbilical cord blood at CorCell, a private bank in Philadelphia. The child is now doing well and is in complete remission 20 months after cord blood transplantation (Hayani, 2007).

8 Spanish Regulations: the case of the Infante's cord blood

This controversy took a political turn in Spain when in May 2005, Prince Philip, heir to the Spanish throne, had the umbilical cord blood of his daughter, the Infante Eleonor, frozen in a private bank. A sample of royal blood is now stored by Cord Blood Registry, one of the largest private umbilical cord blood banks in the USA. The public uproar and media pressure forced the Spanish government to review its national legislation and authorise private banks for directed UCB donations, though the practice will be strictly regulated.

These private banks will not be allowed to make a profit: they must reinvest their earnings and cannot distribute dividends. The Spanish bill also provides that private banks must disclose the HLA types of their grafts in national registries, and in the case of medical emergencies, they will be required to sell the family-owned units for allogeneic transplantations. In other words, non-directed donations will always be given priority over directed donations. Private banks will have to comply with the quality criteria in force in Spain with regard to graft collection, typing, storage and transportation. They will undergo regular inspections by the *Organización Nacional de Trasplantes* (ONT), which will issue renewable four-year licences to each private bank. The information provided to parents will also be monitored, especially concerning the therapeutic applications of UCB. Lastly, exports will be authorised for medical reasons, on condition that the graft does not meet any national therapeutic needs.

9 Bioresources and dependencies

The growth of UCB stocks in public banks is driven by the need for a self-reliant national health system that can offer quality care to all its citizens, regardless of their ability to pay or their ethnic origin. Public banks in some countries are unable to satisfy the demand for national transplantations through their own graft collections. These countries are forced to import stem cells from other countries. Cord blood unit imports raise several issues, among which are their very high price (up to €23,000) and the uneven quality of the grafts according to the country of origin. These issues create a dependency that other countries would like to overcome by developing their own stocks of national grafts. Their goal is to firstly satisfy national needs, and then, if possible, to export cord blood units in order to increase the revenues of their public banks to consolidate their financial foundations.

10 Defining the optimum size of a national inventory

UCB is an expensive resource, therefore, judicious planning of banking programmes with high quality standards is necessary to prevent economic losses (Sirchia et al., 1999). The ideal stem-cell bank would include a sufficient variety of HLA types to allow every potential recipient to receive a good match. However, a bank structured in this way would require the creation and maintenance of an enormous number of grafts, at a huge financial cost. Bok et al. (2004) analyse this challenge through two exclusive strategies:

- The coverage-maximizing strategy makes stem-cell therapies biologically accessible to the greatest number of people, but in North America and Europe; those people would be overwhelmingly white Caucasians.
- The ethnic-representation strategy would provide coverage for the same proportion of people from each ethnic group, but it could cover fewer people overall (Bok et al., 2004).

A Malthusian dilemma opposes the utilitarian and humanistic approaches: which strategy should be adopted? Through the US National Marrow Donors Program (NMDP) and other registries worldwide, nearly 75% of Caucasians, but far fewer racial minorities, find suitably HLA-matched donors (US General Accounting Office (GAO), 2002). Current use of allelic typing for HLA-A, -B, -C, -DRB^1 and DQB^1 has significantly decreased the probability of finding a fully HLA-matched donor, despite the availability of some ten million bone marrow donors worldwide. Some ethnic groups are, indeed, under-represented in current bone marrow registries – in particular, Blacks, Asians and Hispanics – both because of an insufficient number of donors and because of the diversity of HLA types (Ballen et al., 2002). To resolve these disparities, collection in cord blood banks is now specifically aimed at these minorities through an internationally coordinated Netcord programme (Meyer et al., 2005).

In line with this ethnic-representation strategy, the American Congress passed the *Stem Cell Therapeutic and Research Act* in December 2005 to expand the capacity of its public banks: $79 million dollars were invested with the goal of attaining approximately 250,000 cord blood units for 300 million inhabitants, i.e. a target ratio

of roughly eight units per 10,000 inhabitants. This target ratio is also the objective in Asian countries such as Japan, China and South Korea (Table 1).

Table 1 Number of CBU per inhabitant

	Country	*Number of inhabitants (million)*	*Number of CBU*	*Number of units per 10,000 inhabitants*
1	Australia	19.7	11,565	5.8
2	Belgium	10.2	4,903	4.8
3	Finland	5.2	2,311	4.4
4	Spain	40.2	16,831	4.1
5	Israel	6.1	2,043	3.3
6	USA	290.3	87,333	3.0
7	Italy	58.0	14,082	2.4
8	Singapore	4.4	834	1.9
9	Netherlands	16.1	2,889	1.7
10	Germany	82.3	13,353	1.6
11	Japan	127.2	19,889	1.5
12	Czech Republic	10.0	1,451	1.4
13	UK	60.0	5,889	0.9
14	Switzerland	7.3	686	0.9
15	France	63.0	5,329	0.8
16	Argentina	38.7	70	0.01
17	Poland	38.6	41	0.01

Source: BMDW, ESSEC, January 2006

In France, this ratio was 0.8 in February 2006: with approximately 5300 units stored for 63 million inhabitants. France ranks 15th worldwide in the number of units per inhabitant, although this country pioneered the first cord blood transplantation in 1987.

In addition to the competition between public and private banks, there is also competition between the public banks themselves, which are seeking to achieve a critical size that would allow them to limit imports and maximise exports. The optimum critical size of a national bank is difficult to gauge because it is determined directly by the state of scientific progress: cord blood cells are used to treat an increasing number of diseases and new therapeutic applications create new demands. However, the size of a national bank hinges on five convergent objectives:

- meet the needs of patients waiting for marrow transplants
- improve the representation of ethnic minorities in public banks
- develop umbilical cord blood transplants for adults
- meet the needs of partially compatible double-graft transplants
- step up research on umbilical cord blood in regenerative medicine.

11 The Singapore cord blood bank

With an objective of 10,000 units for a population of 4.4 million, the Singapore cord blood bank was created in 2005 with a target ratio of 23 units per 10,000 inhabitants by 2010. This ratio is justified by the ethnic diversity of the Singaporean population. In 2005, the Chinese living in Singapore had a 20% chance of finding a good match, while that for Malays and Indians is significantly lower. The quality and the quantity of bioresources in Singapore will contribute to attracting more medical tourism from South East Asia. The final cost of the Singapore cord blood bank is estimated at around 15 million Singapore dollars or €7.4 million (Alsagoff, 2006).

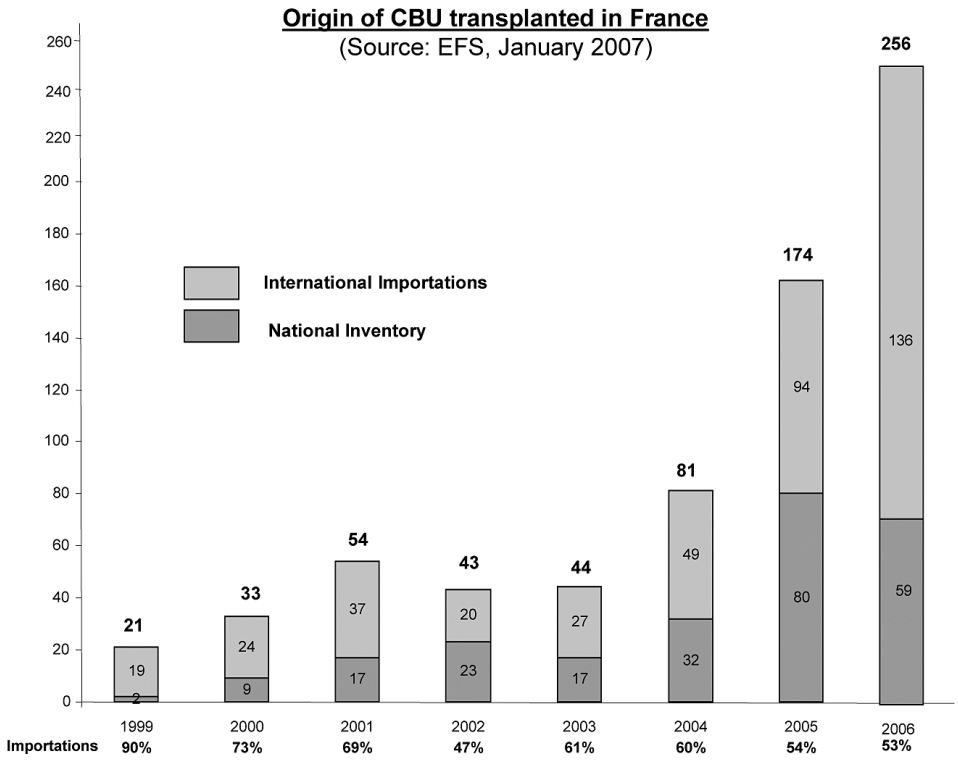
The decision to invest public money in a cord blood bank is fuelled by the shortcomings of the bone marrow registry in Singapore: the national Bone Marrow Donor Program (BMDP) had 35,000 donors by 2005, with less than a 5% probability of finding a match. In order to achieve a match probability of 80%, one million bone marrow donors would have been required. Beyond the difficulty of recruiting these donors, the cost to resize this registry was estimated by SingHealth at around 500 million Singapore dollars (€247 million). Public resources are always scarce, and their prudent allocation is a moral imperative: from an economic standpoint, the cord blood bank was found to be more cost-effective. Furthermore, umbilical cord blood units have a number of therapeutic advantages over bone marrow including direct availability, lower risks of graft-versus-host disease, possibilities of mismatch transplantations, and potential therapeutic applications for regenerative medicine. On all those accounts, Singapore, like Japan, has decided to invest massively in a national cord blood bank.

12 The French paradox

France is a singular case: on the one hand, it imports more than half its cord blood graft requirements each year; on the other hand, it is the leading UCB exporter in Europe. This paradox is due to the fact that France does not have enough grafts to meet the ethnic diversity of its population, while the excellent quality of its grafts allows it to export a large number of units. Between 1999 and 2005, 270 units of UCB were imported from international banks (60%), while 180 units (40%) came from the French inventory (source: ABM, 2005). Over the past five years, the number of imports constantly exceeded the number of transplantations performed using national stock, with an average import ratio of 65% (see Figure 2).

To meet its annual needs for UCB transplantations, France therefore seems to be dependent on the UCB bioresources it imports each year from other countries. Since the average price of an imported graft (approximately €18,000) is much higher than the cost of a graft stored in France (€2100), a budget of €4.29 million could have been saved between 2000–2005 if those same grafts had been stored in French public banks. Rather than investing in imports, public health would allow major savings in France by expanding its national UCB stock, thus becoming more self-reliant for the bioresources required to meet its national needs.

Figure 2 Origin of CBU transplanted in France



While France lags behind in terms of quantity of stored grafts, it has set some of the highest national standards with regard to the quality of its grafts, ranking it among the world leaders in UCB exports. Created in 1999, the objective of the French inventory was to stock 5000 units of UCB over five years, according to stringent quality criteria. These criteria included the haematopoietic stem cell ratio (CD34+ cells) contained in the graft, the volume of the graft (> 80 ml), and infectious testing performed on mothers at the time of the donation and after a quarantine period. With a sales rate of 6.9% in February 2006 (5329 units stored and 365 units distributed since 1999), France is the leading graft exporter in Europe and number three worldwide (source: Netcord, ESSEC, 2006). This shows the importance of the quality criteria originally defined by the Foundation for Accreditation of Cellular Therapy (FACT). While very costly, these measures offer obvious therapeutic benefits as well as indirect financial benefits, since French graft exports have doubled in two years (28 units exported in 2003, 42 units in 2004 and 62 units in 2005).

13 Resizing the French inventory

In 2004, of the 903 French patients waiting for a marrow graft, 243 patients received transplants (27%), including 58 from imported grafts; 660 patients did not receive transplants because no marrow grafts were available (73%) (source: ABM, 2005).

These results are similar to those of the NMDP in the USA in 2002. Now that the clinical benefits of UCB transplants for both children and adults have been scientifically proven, the French bank should be resized to meet the national demand. With the sharp increase in international competition between public and private UCB banks, and between the public banks themselves, the real challenge for France is to increase the size of its bank, while maintaining the excellent quality of its units. The Eurocord association plans to meet this challenge by working with the Etablissement Français du Sang (EFS), l'Assistance-Publique – Hôpitaux de Paris (AP-HP) and the Agence de la Biomédecine (ABM).

14 Self-sufficiency of public banks

The costs of cord blood banking are high and may put some public banks at risk if they do not receive adequate public funding. Private banks may take a number of years to break even and risk closure if they do not acquire a critical mass of stored units. Cord blood banks differ from other organisations involved in tissue or organ donation because they produce a tangible asset that, when sold, allows for cost recovery, and makes self-sufficiency possible. In 2004, 57% of the units distributed by the French inventory were exported, generating 73% of the annual umbilical cord blood resources (source: EFS, 2005). Self-sufficiency is only feasible, however, if the banks own the cord blood units they collect and are allowed to charge for those they distribute for transplantation. Cord blood banks have already made considerable upfront and continuing investment in establishing operations and building inventory. Public bank self-sufficiency is based on demand for cord blood units and the transplant community's level of trust in the reliability of cord blood, including the level of safety and effectiveness. However, some banks are financially threatened by patent controversies.

15 Patent controversies

In March 2006, there were close to 100 patents covering umbilical cord blood biotechnologies. The main patents concern cord blood cell collection and cryopreservation, in vivo and in vitro cell expansion, and isolation and differentiation of cell lineages based on cord blood. The main companies that hold these patents are Amgen, Viacell, Baxter, Celgene, Cryocell, Ethicon, Gamida Cell, Histostem, Stemcyte and Saneron Cell Therapeutics.

Concerns about the extent of commercialisation of cord blood banking have been highlighted by recent patent litigation. A private biotechnology company, PharmaStem Therapeutics Inc., has claimed that its patents covering collection, cryopreservation, storage and the use of cord blood entitle it to licensing fees (Steinbrook, 2004). To this end, the company brought a suit against private banks that had not signed their licensing agreement and sent letters to approximately 25,000 obstetricians asking them not to collect cord blood for five cord blood banks that had not obtained a license with PharmaStem Therapeutics Inc., claiming potential liability for patent infringement. Following a US federal court order in July 2004 prohibiting PharmaStem from further contacting obstetricians, due to the fact that it had made 'false and

misleading' statements to obstetricians, a September 2004 ruling found that PharmaStem had failed to prove infringement of its patents because the banks did not sell or offer to sell cryopreserved cord blood. Most recently, the US patent office re-examined one of the two PharmaStem patents in question and rejected the company's related claims. There are four private cord blood banks that are fighting PharmaStem in court over the enforcement of these patents: Cord Blood Registry, Corcell, Cryo-Cell, and Viacord. All of these lawsuits have been stayed pending the outcome of the appeals over whether the patents are valid. Meanwhile, the remaining cord blood banks which purchased PharmaStem licensing agreements will continue to pay royalties until PharmaStem has exhausted all appeals (Verter, 2006).

16 Beyond the ethical deadlock of regenerative medicine

The current ethical dispute over human embryonic stem cells focuses, not on their potential usefulness but on their source (surplus embryos from IVF), or their bioengineering (therapeutic cloning). Umbilical cord blood represents an alternative solution to reach the same goal – producing pluripotent stem cells – through uncontroversial means. Qualified as *restus nullus* until the end of the eighties, the umbilical cord was considered as disposable waste. A natural organic pharmacopoeia without the moral resonance of the human embryo, umbilical cord blood offers a point of equilibrium between respect for human life, medical hope for patients and scientific promise in stem cell research.

Moreover, there is a serious shortage of matched bone marrow for transplantation, and cord blood banks could help relieve it. Expanding the diversity of HLA-types in public banks would help reach the ultimate goal of regenerative medicine: one compatible match for each patient, available immediately, with high quality standards and equal access to biological resources, including for ethnic minorities. Supported by two decades of clinical research, umbilical cord blood could represent the preferential source of stem cells in the future, not only because it is clinically effective, but also because it is ethically uncontroversial.

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