Review

Cord Blood Banking in the Arab World: Current Status and Future Developments

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Article history:
Received 10 October 2014
Accepted 14 January 2015

Key Words:
Cord blood banking
Arab world
Regulation
Ethics
Education

Abstract
Umbilical cord blood transplants are now used to treat numerous types of immune- and blood-related disorders and genetic diseases. Cord blood (CB) banks play an important role in these transplants by processing and storing CB units. In addition to their therapeutic potential, these banks raise ethical and regulatory questions, especially in emerging markets in the Arab world. In this article, the authors review CB banking in five countries in the region, Jordan, Saudi Arabia, Egypt, Qatar, and the United Arab Emirates, selected for their different CB banking policies and initiatives. In assessing these case studies, the authors present regional trends and issues, including religious perspectives, policies, and demographic risk factors. This research suggests strong incentives for increasing the number of CB units that are collected from and available to Arab populations. In addition, the deficit in knowledge concerning public opinion and awareness in the region should be addressed to ensure educated decision-making.

Introduction

In 1988, the first stem cell transplant using umbilical cord blood (CB) was performed to treat a pediatric patient suffering from Fanconi’s anemia. Ten years later, the first CB transplant was carried out in the Arab world, and as the number of transplants continues to increase, the infrastructure for CB collection and storage has expanded [1]. The establishment of CB banks has expanded rapidly over the past decade, fueled largely by promising advances in CB transplantations.

The Arab world in particular is witnessing a proliferation in CB banks, often preceding regulatory policies and public discussions. Despite varying economic and political priorities in the region, several unique factors, including fertility rate and disease incidence, relate especially to CB banking (Table 1). Most controversial are the for-profit CB banks that have found an enthusiastic—but arguably under-informed—clientele in Arab countries. In addition, research on public opinion is needed to help create strong national and regional policy frameworks for CB banking programs.

Banking Models: Public, Private, and Hybrid

The discovery that CB contains hematopoietic stem cells (HSCs) turned the umbilical cord from disposable waste into a valuable resource. CB transplants have become standard therapies for numerous indications, and hundreds of clinical trials are being carried out internationally to investigate CB’s therapeutic potential for a wider range of disorders, including autism, diabetes, and cerebral palsy. More than 3 million CB units are in storage around the world, with about 650,000 in public banks and 2.5 million in private facilities [2].

CB is collected after childbirth without adversely affecting the mother or infant. After collection, the bank tests the unit for diseases and viability for transplant and then freezes the eligible units until needed for transplant or, in some cases, research. CB is used for both allogeneic (related and unrelated) and autologous transplants. CB can be donated to a public bank where it can be accessed by any patient in need of a transplant. Conversely, parents can pay to store the CB unit in a private bank for family use. Hybrid banks have varying combinations of both public and private storage.

In the Arab world, only a few public CB banks exist (Table 2). Public banks collect and process donated CB
These countries were chosen for their unique policy and CB banking initiatives and programs as well as relevant demographic factors. Information is included on demographics: population in millions, percent of population of Arab ethnicity (Arab), and total fertility rate (Fert)\(^1\): economics: gross national income per capita (GNI) and percent of gross domestic product for health expenditures (Health $); and health: hospital bed density (Hosp beds) and age-standardized incidence rates of leukemia and lymphoma (both Hodgkin and non-Hodgkin).

- Total fertility rate is a better measure of fertility level than crude birth rate and is the average number of children that would be born per woman if all women lived to the end of their childbearing years and bore children according to a given fertility rate at each age.
- GNI per capita indicates the average national income, converted to US dollars using the World Bank Atlas method to smooth fluctuations in prices and exchange rates.
- Hospital bed density is the number of hospital beds per 1000 people, serving as a general indicator of patient service availability.
- Age-standardized rate is the number of new cases or deaths per 100,000 persons per year; it is the rate a population would have if it had a standard age structure.


without a fee and assume ownership of the unit to sell it to a transplant center for the first patient in need. Public banks are not financially self-sustainable and are primarily funded by the government, charitable sources, and revenue from exporting CB units to transplant centers. Although there are no mandatory international regulations on public CB banks, to register CB units on a database accessible by transplant centers, the bank usually has to meet certain accreditations or standards. For example, the Foundation for the Accreditation of Cellular Therapy (FACT) accredits CB banks using the NetCord-FACT quality standards, which are universally recognized by transplant centers around the world. Currently, only 2 banks in the Arab world—1 in Riyadh and 1 in Dubai—have met the NetCord-FACT requirements to participate in NetCord’s international online database of CB units (Table 2). Governments may have alternative or additional national policies to regulate CB banks.

Several public CB banks have begun offering a “family-directed” donation program that allows families with either a current transplant need or a history of diseases treatable with CB to donate the unit at minimal-to-no cost to the family member in need [3]. This type of storage requires prescreening and counseling to inform families about options. However, it is generally considered a financially, medically, and ethically sound option.

Private CB banks have attracted many clients among Arab populations—their services currently outnumber public banking options (Table 2). However, most private banks are US- or UK-based and store the CB units in facilities outside of the Arab world. Private banks advertise their services to the general public and charge clients for CB collection, processing, and storage, which total about $4000 per unit for 20 years of storage. With a low average income in many Arab countries—$4950 in Jordan and $3160 in Egypt—these costs are prohibitive to the majority of the populations (Table 1) [4].

Private CB banks depend on revenue from clients and therefore may be driven by economic competition to use ethically questionable recruitment tactics. Populations that are unaware of other CB banking options may be especially vulnerable to these advertisements. For example, company representatives may approach parents at emotionally vulnerable times (eg, during labor), present biased information about CB storage as “biological insurance” for the newborn, and give a false impression about the likelihood of needing a CB transplant. Data about autologous CB transplants are limited, but research has estimated the likelihood of needing one during the first 20 years of life (ie, when the frozen unit is still viable) to be very unlikely, ranging from 1:2500 (or .04%) to 1:200,000 (or .0005%), depending on inclusion criteria [5]. In addition, the quality of the CB unit may be inadequate for transplant because regulations for private banks are often less stringent and many private CB banks store the collected CB unit regardless of its viability.

A new type of CB bank is the hybrid model, which offers a combination of public and private CB storage. Some hybrid banks store a portion of the CB unit publicly and another portion privately, whereas others give parents the choice to either donate the CB for public storage or keep it privately. In either case, hybrid banks can use the revenue from private storage to offset the costs of the public side and can have the added advantage of providing parents with a choice.

### CASE STUDIES FROM THE ARAB WORLD

Five countries in the Arab world—Jordan, Saudi Arabia, Qatar, Egypt, and the United Arab Emirates (UAE)—stand out for their unique CB banking policies or new program initiatives and investments (Tables 1 and 3). Although private CB banks dominate in the region, several public banks are already in operation, and additional plans are in progress.

#### Jordan

Jordan is a regional standout in medical infrastructure and scientific research. It currently spends the highest percentage of its gross domestic project on health among all Arab countries. The King Hussein Cancer Center (KHCC), operated by the Ministry of Health, is at the helm of HSC transplant activity. In addition, Jordan recently passed a

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Table 1

<table>
<thead>
<tr>
<th>Country</th>
<th>Population</th>
<th>Arab</th>
<th>Fert</th>
<th>GNI</th>
<th>Health $</th>
<th>Hosp Beds</th>
<th>Leukemia</th>
<th>Lymphoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td>7.93M</td>
<td>98%</td>
<td>3.16</td>
<td>$49.5k</td>
<td>8.4%</td>
<td>1.8</td>
<td>6.1</td>
<td>8.2</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>27.3M</td>
<td>90%</td>
<td>2.17</td>
<td>$26.2k</td>
<td>3.7%</td>
<td>2.2</td>
<td>3.8</td>
<td>7.9</td>
</tr>
<tr>
<td>UAE</td>
<td>5.63M</td>
<td>13%</td>
<td>2.36</td>
<td>$38.6k</td>
<td>3.3%</td>
<td>1.9</td>
<td>3.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Egypt</td>
<td>86.9M</td>
<td>99%</td>
<td>2.87</td>
<td>$31.6k</td>
<td>4.9%</td>
<td>1.7</td>
<td>5.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Qatar</td>
<td>2.12M</td>
<td>40%</td>
<td>1.92</td>
<td>$85.5k</td>
<td>1.3%</td>
<td>1.2</td>
<td>4.9</td>
<td>7.7</td>
</tr>
</tbody>
</table>
regulatory law on stem cell research and therapy—a first in the region.

KHCC was founded in 1997 and began its HSC transplant program in 2003. It performs approximately 100 HSC transplants from bone marrow each year and is currently the only program in Jordan that carries out CB transplants, procuring units from international sources [6,7]. CB transplants have shown to help bypass long waiting times, which can reach 3 years for thalassemia patients in Jordan [8].

KHCC is currently building a stem cell unit that includes CB storage space. This new facility will include the first public CB bank in Jordan, which will be funded through revenue generated by the KHCC transplant center and additional support from the KHCC Foundation. KHCC may later adopt a hybrid model by opening a section for private storage to increase funding sources. In anticipation of the growth of the HSC transplant program and the demand for CB units, KHCC is planning to establish a national CB registry database so that patients can locate donors [9].

Several private companies offer CB collection and storage services in Jordan. However, with an average income of less than $5000, the high costs are only accessible for the economically elite. For example, BabyCord Jordan, a US-based private CB bank, charges over $2000 for the initial collection and first year of storage and an additional $200 each year thereafter. The company recently built a storage facility in Jordan and applied for a license to expand its service, making it the first private CB facility in the country.

In January 2014, after several years of meetings and draft laws, the Jordanian government passed new stem cell

### Table 2

Current CB Banking Options in the Arab World

<table>
<thead>
<tr>
<th>CB Bank</th>
<th>Type</th>
<th>Storage Location</th>
<th>Collection Office Location(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BabyCord</td>
<td>Priv</td>
<td>USA (Boston), Jordan (Amman)</td>
<td>Jordan</td>
</tr>
<tr>
<td>Biovault Family</td>
<td>Priv</td>
<td>UK (Plymouth)</td>
<td>Lebanon, UAE</td>
</tr>
<tr>
<td>Cells4Life</td>
<td>Priv</td>
<td>Egypt (Cairo)</td>
<td>Egypt</td>
</tr>
<tr>
<td>Cells4Life</td>
<td>Priv</td>
<td>UK (Burgess Hill, Essex)</td>
<td>Bahrain, Egypt, Jordan, Kuwait, Lebanon, Qatar, Saudi Arabia, UAE</td>
</tr>
<tr>
<td>Center for Stem Cell Research &amp; Regenerative Medicine</td>
<td>Publ</td>
<td>Egypt (Assiut)</td>
<td>Egypt</td>
</tr>
<tr>
<td>Cryo-Save</td>
<td>Priv</td>
<td>UAE (Dubai)</td>
<td>Egypt, Kuwait, Oman, Saudi Arabia, UAE</td>
</tr>
<tr>
<td>DCRC</td>
<td>Hybr</td>
<td>UAE (Dubai)</td>
<td>UAE</td>
</tr>
<tr>
<td>Future Health Biobank</td>
<td>Priv</td>
<td>UK (Nottingham), Switzerland</td>
<td>Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Qatar, Saudi Arabia, Syria, UAE</td>
</tr>
<tr>
<td>KAIMRC</td>
<td>Publ</td>
<td>Saudi Arabia (Riyadh)</td>
<td>Saudi Arabia</td>
</tr>
<tr>
<td>KHCC</td>
<td>Publ</td>
<td>Jordan (Amman)</td>
<td>Jordan</td>
</tr>
<tr>
<td>Precious Cells</td>
<td>Priv</td>
<td>UK (Middlesex)</td>
<td>Jordan, Lebanon, UAE</td>
</tr>
<tr>
<td>Smart Cells</td>
<td>Priv</td>
<td>UK (West Drayton)</td>
<td>Egypt, Jordan, Kuwait, Lebanon, Syria, UAE</td>
</tr>
<tr>
<td>Sultan Qaboos Univ. Hospital</td>
<td>Publ</td>
<td>Oman (Muscat)</td>
<td>Oman</td>
</tr>
<tr>
<td>Virgin Health Bank</td>
<td>Priv, Hybr</td>
<td>Qatar (Doha)</td>
<td>Qatar</td>
</tr>
</tbody>
</table>

Three types of bank (Type) collect cord blood in the region. The majority are private facilities (Priv) that store the units outside of the region. Several public banks (Publ), as well as 2 hybrids (Hybr), have opened. Two banks are NetCord members (*)

* Indicates the CB bank storage facility is currently under construction.

† Indicates CB banks that are Provisional Members of the NetCord consortium. These banks must comply with NetCord-FACT quality standards and have access to NetCord's online registry, so patients across the world can access their CB inventory.

### Table 3

Timeline of Major CB Banking Developments in the Arab World

<table>
<thead>
<tr>
<th>Year</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>First CB transplant is performed in Arab world</td>
</tr>
<tr>
<td>2003</td>
<td>SA: KFSH-RC begins performing CB transplants (from imported units)</td>
</tr>
<tr>
<td></td>
<td>Muslim World League's Jurisprudential Council issues a fatwa approving CB for research and therapy</td>
</tr>
<tr>
<td>2006</td>
<td>UAE: DCRC opens first CB bank in the region, as a public–private hybrid model</td>
</tr>
<tr>
<td>2007</td>
<td>EG: National Blood Policy is approved with procedural guidelines for CB collection and storage</td>
</tr>
<tr>
<td>2009</td>
<td>QA: Virgin Health Bank moves its headquarters from London to Doha</td>
</tr>
<tr>
<td>2011</td>
<td>QA: Virgin Health Bank is granted the first (and only, to date) license for CB procurement, processing, and storage</td>
</tr>
<tr>
<td></td>
<td>SA: KAIMRC opens the country's second public CB bank and creates the Saudi Donor Registry</td>
</tr>
<tr>
<td>2012</td>
<td>EG: National Stem Cell Committee is created and tasked with establishing regulations for stem cell research and therapy as well as a public CB bank</td>
</tr>
<tr>
<td>2013</td>
<td>QA: Stem cell research policy is enacted into legislation, allowing research using CB stem cells</td>
</tr>
<tr>
<td>2014</td>
<td>EG: Center for Stem Cell Research and Regenerative Medicine opens in Zewail City of Science &amp; Technology</td>
</tr>
<tr>
<td>2015</td>
<td>JO: New stem cell research law is passed, including regulations for CB banking</td>
</tr>
<tr>
<td>2016</td>
<td>JO: Projected opening of the country's first public CB bank, located at Assiut University, in partnership with Zewail City of Science &amp; Technology</td>
</tr>
</tbody>
</table>

Over the past decade, several Arab countries have had significant activities related to CB banking, starting primarily with Saudi Arabia (SA) and the UAE. More recently, new developments have been centered in Egypt (EG), Qatar (QA), and Jordan (JO).
research and therapy guidelines, which were approved by the Ministry of Education, the National Committee for Science and Technology Ethics, and Jordan’s Religious Council (Maglis Al-Iftaa) [10]. The law is the first in the Arab world to include CB banks and is permissive toward adult stem cells, including those derived from CB, and puts strict regulations on private banks by requiring licensure and regular monitoring of facilities and procedures. In addition, the law mandates a national committee composed of members from relevant fields who are tasked with evaluating a company’s legal compliance at each stage of the license granting procedure. The national committee will also update the stem cell regulations in concordance with new advances in the field of stem cell research and therapy, making the law not only dynamic but also open-minded and conducive toward scientific research.

**Saudi Arabia**

The Saudi bioethics committee, established in 2002 by royal decree, permits research using stem cells, including those procured from CB [11]. Policies related to CB and CB banking are based on the 2003 fatwa (Islamic legal ruling) issued by the Muslim World League’s Islamic Jurisprudential Council. The ruling permits the use of stem cells from “the placenta or umbilical cord with the permission of the parents” for research and therapy [12]. The Saudi Ministry of Health also formed a national committee tasked with overseeing CB banks, creating licensing procedures, and establishing regulations [13]. In early 2011, the Ministry of Health closed several offices in the Kingdom that were allegedly coordinating with foreign private banks and advertising treatment options using prohibited, unlicensed approaches [14].

In 2003, the King Faisal Specialist Hospital and Research Center (KFSH-RC) began performing transplants using CB units imported from international registries. A public bank was created in 2006 at KFSH-RC, which now stores over 4600 units. As of 2013, it had transplanted 121 locally stored units to 108 patients (103 children, 5 adults) [15,16]. In 2010, over 10% (25 of 119) of its allogeneic HSC transplants were performed using CB and 88% (22 of the 25) of the CB units were procured locally [17]. The number of local CB units transplanted annually increased from 1 to 30 between 2008 and 2011, with a concomitant decrease in the number of international units used, from 29 to 3 [15]. KFSH-RC was officially recognized as a FACT-accredited organization in 2012, joining the NetCord consortium as a provisional member and becoming 1 of 2 member banks in the Arab world.

KFSH-RC’s bank is extending its collection and storage capabilities, with plans to cooperate with local hospitals to collect CB units from different regions in Saudi Arabia and to build a new facility at King Abdullah Center for Kidney Diseases. CB units from Saudi donors have demonstrated a high degree of matching for allogeneic transplants in Saudi patients [18]. The bank claims to have achieved 90% coverage for all Saudis who do not have a matching family donor [16]. Transplanting locally stored CB units is significantly cheaper than using international units—$8000 versus $40,000, respectively.

A second CB bank opened at King Abdullah International Medical Research Center (KAIMRC) in 2011, operated by the National Guard Health Affairs—the Kingdom’s major body that oversees its medical complexes [19]. This bank accepts CB donations for either allogeneic transplant or research. It now stores approximately 2000 CB units, and the HSC transplantation program has carried out close to 200 transplants over the past 3 years [20]. Notably, the National Guard Health Affairs established the first stem cell donor registry in the region in an effort to increase matching rates among Arab citizens and now lists over 5000 donors [21].

**United Arab Emirates**

The Dubai Cord Blood and Research Center (DCRC), which opened in June 2006, was the first CB bank in the Arab world [22]. As a hybrid bank, it is currently the only facility in the UAE to offer public storage. CB collection occurs at designated hospitals run by the Dubai Health Authority, although transportable collection kits are now being used for childbirths outside of these centers [23]. Like the Saudi bank at KFSH-RC, DCRC’s CB bank is a provisional member of the NetCord consortium, with a set goal of becoming a full member in the future.

DCRC increased its number of registered CB units between 2011 and 2012 by nearly 50%. This surge stems from education and awareness campaigns it implemented after survey results revealed parents were lacking information about CB banking. As of 2013, the facility had stored over 3300 units (less than 20% of which are in public storage) and had transplanted 9 units, all of them in children [22]. DCRC subsidizes the cost of private banking at approximately $2500 for collection and 25 years of storage.

Several private CB banks provide collection and banking services to the UAE. All of them are more expensive than DCRC’s private storage option, and all but 1 store the CB units abroad. Cryo-Save Arabia opened in 2006 and is the largest private CB facility in the Arab world. The bank stores units in Dubai Biotechnology and Research Park (DuBiotech) that have been collected from countries throughout the region, including Bahrain, Egypt, Kuwait, Lebanon, Oman, Qatar, and Saudi Arabia. It has received accreditation from the US Food and Drug Administration as well as a clinical operating license from the Center for Healthcare Planning and Quality, the independent regulatory body that sets standards for companies that operate at Dubai Healthcare City [24].

**Egypt**

Egypt’s Ministry of Health and Population (MOHP) developed an extensive policy on CB banking using guidelines and codes of ethics from the United States and Europe as a template. In 2007 it approved a National Blood Policy with procedural guidelines for CB collection and storage to be overseen by the country’s National Blood Transfusion Standards [25]. Before a CB bank can operate in Egypt, it must receive approval from Al-Azhar University, a preeminent center for Islamic learning in Cairo. Egypt permits both private and public banking in the country, as long as certain regulations are fulfilled to minimize the potential of commercial exploitation.

Egypt’s HSC transplant program, established in 1989, has been slow to develop and now performs more transplants using peripheral blood than bone marrow [26]. Growing political mistrust among Egyptians since 2013 has resulted in a decrease in blood donations in general, so CB donation rates may also be suffering [27]. However, research on CB transplants is taking place at several universities and research centers in the country, including a clinical trial on autologous CB transplants in neonates at Ain Shams University in Cairo [28].

In 2011 the MOHP created the National Stem Cell Committee tasked with establishing regulations for stem cell
research and therapy and a national stem cell bank. The MOHP also inaugurated a new stem cell research center at Sheikh Zayed Hospital in 2012, and Zewail City of Science and Technology opened a Center for Stem Cell Research and Regenerative Medicine in 2013 [29]. Zewail City is also partnering with Assiut University to build a public CB bank [30].

The slow development of public CB banking in Egypt is likely linked to the political and funding instabilities in the country. Several private banking options are available, including CellSafe, which acquired a MOHP license in 2008 and has stored over 1000 CB units for an initial $1600 fee and $140 annually thereafter [31]. Stem-Health S.A., a FACT-accredited family CB bank, also has a license to establish a private bank in Egypt, but to date no development has started [32].

Qatar

In 2009 Virgin Health Bank moved its headquarters from the United Kingdom to Qatar. CB collection was launched in 2010 at Hamad Medical Corporation’s Women's Hospital and has now expanded to several other facilities [33]. No reported CB transplants have taken place in Qatar yet. However, the National Center for Cancer Care & Research has a 5-bed bone marrow transplantation unit specializing in autologous HSC transplants following Hamad Medical Corporation guidelines [34].

Virgin Health Bank, the only CB bank in Qatar to receive a license from the Supreme Council of Health, is located in Qatar Science and Technology Park. It first launched a private storage option and later added hybrid “community banking” that stores 5 mL of the CB unit privately and the rest of the unit publicly “for use in the wider patient community” [35]. This service depends on the future development of cell expansion procedures because 5 mL is not adequate for transplant.

Qatar’s Supreme Council of Health developed a stem cell research policy in 2010, which was approved by the country’s National Research Ethics Committee in 2011. These guidelines allow for research involving stem cells from CB as well as human embryos. In 2012, following the Qatar International Conference on Stem Cell Science and Policy, the guidelines were enacted into legislation and are an important step to increasing Qatar’s capacity for CB research and transplants [36].

ARAB WORLD–RELATED ISSUES FOR CB BANKING

Several issues concerning CB banking relate uniquely to the Arab world. With religious permissibility, considerable biological risk factors, and sizeable economic considerations, the region would benefit from greater availability of public CB units. Therefore, public CB banking programs—especially those with family-directed donation options—are overwhelmingly favored over private CB banking in Arab countries.

Public Accessibility and Acceptance

Although the umbilical cord itself is not given significance in Islam, parts of the body, including blood, are often given special consideration. Many Muslims consider medical and scientific research to be fard kifaya (“a collective religious duty”) as supporting the principle of maslaha (“promoting public good”). In general, the judgments on permissible versus impermissible actions in Islamic law are derived from the Qur’an and the hadith (actions and sayings of Prophet Mohammed). If these sources do not specifically reference the issue, such as using CB, and if no precedent is available, Islamic jurisprudential scholars follow a specific methodology of analysis to issue a fatwa [12]. In addition to the Muslim World League’s fatwa in 2003, which permits using CB for research and therapy with parental consent, Islam encourages public donation over private storage. With Muslim-majority populations in these countries, the cultural viewpoints support voluntary CB donation and its use in medical treatments and research.

Public awareness is a major component of CB donation success. Non-white populations have difficulty finding registered HSC donors—whether from bone marrow, peripheral blood, or CB. Of the 20 million HSC donors registered globally, fewer than 50 are registered in the Arabian Gulf countries [37]. Over 60 registries exist worldwide, but the only 1 available in the Arab world opened in 2011 at KAIMRC’s CB bank. The probability of a Jordanian finding a matching unrelated stem cell donor on an international registry has been estimated to be only 2% to 5%, which is significantly lower than the 50% to 60% likelihood for patients of white descent [38]. Even if an allogeneic donor were found, the logistics of timing the donation and transplant overseas would be difficult. Public CB banks can help to fill this gap by providing an alternate source of HSCs for the diverse and growing Arab population.

In addition to traditional donation procedures, family-directed donation programs require further infrastructure for prescreening and advising. Health care providers, especially obstetricians, should provide information early in pregnancy about the options for CB banking and encourage public donation over private storage for the general population. Surveys in other countries have indicated strong public support for CB donations, but many parents do not participate because of a lack of awareness [39,40]. Invoking health care providers in CB banking programs is important for decreasing this educational gap and increasing CB donations.

Region-Specific Biological Factors

Three major issues relevant to the Arab world—consanguineous, hemoglobinopathies, and bloodborne disease—justify the need to support public CB banking in the region. Important disease indications for transplant include acute leukemia, bone marrow failure syndromes, and hemoglobinopathies, the latter 2 of which appeared at higher rates in the region than found in Europe. Therefore, CB banking programs that offer both public and family-directed donation programs are especially relevant.

Consanguineous marriages are defined clinically as a union between 2 individuals biologically related as second cousins or closer. High rates of consanguinity have been associated with several diseases treatable with CB transplants, including leukemia, lymphoma, and beta-thalassemia. The rate of consanguinity ranges between 28% and 63% in Jordan, over 50% in the current Qatari and Saudi generations, and up to 60% to 80% in rural Egypt [41,42]. Although large family size and intermarriage may decrease the need for unrelated CB transplants, these demographic factors are declining. In the future, it may be increasingly difficult to find related donors as families become smaller [43]. In fact, the number of allogeneic HSC transplants performed in the region steadily increased from the mid-1980s to the mid-2000s, totaling 1078 in Egypt, 251 in Jordan, and 2057 in Saudi Arabia (no data from Qatar or...
the UAE are available) [1]. Furthermore, approximately 40% of Saudis do not have a related donor source, and the likelihood of finding an unrelated donor on Western registries is low [18]. Therefore, alternative donor sources remain essential [42].

Carrier frequencies of hemoglobinopathies are also high in the region, with thalassemias and sickle-cell anemia among the most common single gene disorders in the Arab world [44]. For example, carrier frequency for beta-thalassemia in Egypt is estimated to be 6% to 10%, making HSC transplants an important medical intervention for the population.

Finally, endemic bloodborne diseases in the region present a challenge to CB banking. For example, hepatitis B infects 4.3 million people each year in the Arab world [45,46]. Stringent testing of CB is required to preemptively identify infectious diseases and to ensure CB transplant safety. Both private and public banks should be subjected to equivalent testing regulations. Educational campaigns should also emphasize that necessary steps are taken to ensure safety of the blood so parents are not afraid to either donate or receive CB blood.

**Economic and Policy Incentives for Regional Coordination**

Public CB banks require significant financial support to build a sizable inventory of high-quality, transplantable CB units. Governments can improve transplant opportunities for their populations and reduce the associated costs by creating a national CB registry. Especially for countries with limited budgets, transplanting CB units collected from the country’s public banks is more economical than relying on costly international sources. Higher matching rates of CB transplants among Arab populations because of similar genetic backgrounds and tissue compatibility suggest greater cost-effectiveness of programs in the region [18,47]. Because public CB banks primarily generate revenue by charging transplant centers a fee for procuring CB units, a higher turnover rate of units makes the banks more financially sustainable. However, simply increasing the number of CB units in storage may not be the most financially sound solution. Several countries, including the United States, United Kingdom, and Japan, have conducted population-specific studies to determine the ideal number of CB units in public storage to cover a sufficient percentage of the population while not wasting resources [47-49]. Arab countries should carry out similar analyses to determine their national inventory needs and ideal ratios to develop their programs in a cost-effective manner.

National CB banking programs should consider cooperating to create a regional stem cell donor registry. A more extensive registry of Arab donors will increase donor–patient matching rates and CB unit turnover and minimize shipment costs. A regional registry will also require mandatory and more stringent CB collection and storage regulations as well as coordination strategies between banks and transplant centers. However, these steps will improve long-term outcomes, especially as the need for HSC transplants continues to increase [50]. Stronger therapeutic programs will also help to reduce the economic burden posed by the high prevalence of hemoglobinopathies and other diseases treatable with CB transplants [44].

CB collection practices and the availability of trained medical staff are important for successful transplant outcomes. Collected CB units that fail to meet transplant standards are a waste of resources. For example, staffing shortages at KAIMRC resulted in a collection loss of 40% of the CB units available for donation, and, even then, most collected CB units were later rejected for inadequate quality [51]. Since then, KAIMRC implemented education and awareness programs and staff recruitment initiatives that have positively impacted the CB collection and storage success rates. Other national CB banking programs should also prioritize personnel training to address the current shortfall in transplant availability, data collection, and research [49].

**CONCLUSION**

The demonstrated successes so far of the public CB programs in the Arab world, most notably in Saudi Arabia and the UAE, are positive trends for the region. Major investments to create new public CB banks in Jordan and Egypt, as well as Jordan’s leadership in policy initiatives, are also promising developments. These programs require a commitment to training, education, research, and facilities to ensure their full integration into the national health care infrastructure.

The region is in need of robust policies and programs for HSC transplants, CB banks, and research, especially so it does not fall behind as these fields continue to progress internationally. Governments should engage experts in medicine, policy, and religion to create guidelines for sustainable and effective CB banking programs. Several factors in the region, including population demographics and accessibility of medical treatments, strongly incentivize widening public CB storage capabilities with family-directed donation programs. In addition, the lack of knowledge about public opinion and level of awareness concerning these topics makes research, educational initiatives, and medical staff training even more critical in Arab countries.

**ACKNOWLEDGMENTS**

Financial disclosure: The authors have nothing to disclose.

Conflict of interest statement: There are no conflicts of interest to report.

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