Industry perceptions of the barriers to commercialization of regenerative medicine products in the UK

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Abstract

Aims
Regenerative medicine is an emerging field with the potential to provide widespread improvement in healthcare and patient well-being via the delivery of therapies which can restore, regenerate or repair damaged tissue. As an industry, it could significantly contribute to economic growth if products are successfully commercialized. However, to date, relatively few products have reached the market due to a variety of barriers, including a lack of funding and regulatory hurdles. The present study analyzes industry perceptions of the barriers to commercialization which currently impede the success of the regenerative medicine industry in the UK.

Materials & Methods
The analysis is based on twenty interviews with leading industrialists in the field.

Results
The study revealed that scientific research on regenerative medicine is thriving in the UK. Unfortunately, lack of access to capital, regulatory hurdles, lack of clinical evidence leading to problems with reimbursement, as well as the culture of the NHS do not provide a good environment for the commercialization of RM products.

Conclusions
Policy interventions, including increased translational government funding, a change in NHS and NICE organisation and policies as well regulatory clarity would likely improve the general outcomes for the regenerative medicine industry in the UK.

Keywords: commercialization, regenerative medicine, tissue engineering, barriers

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1 Introduction

The United Kingdom (UK), in line with most developed and some developing economies, has placed significant emphasis on innovation and growth based on the outputs of the science base [1-3]. An area that could provide such science led growth is the emerging industry of regenerative medicine (RM).

The field of regenerative medicine has developed over the past twenty to thirty years bringing together a number of disparate fields including biomaterials engineering, production engineering, cell biology and surgery [4, 5]. Having roots in many disciplines has caused confusion as each group defines the field and the industry from its own perspective [6, 101]. However, a simple definition of regenerative medicine has recently been offered, and appears to have the support of most groups. It is suggested that regenerative medicine "replaces or regenerates human cells, tissues or organs, to restore or establish normal function" [7 p.4].

In the 1990s the precursor of regenerative medicine – tissue engineering – was hailed as a field with the potential for addressing important chronic health problems and enormous financial success [8], resulting in the founding of many companies during that decade [9-11, 12, 101]. The industry has gone through an initial period of growth and high expectations from the beginning of the 1990s followed by a significant contraction between 2000 and 2002, and stable growth to the present [13]. Since that period the industry has regrouped and now appears to be building on more sustainable foundations. The original assumption that RM would develop akin to pharmaceuticals, with blockbuster products, has changed and a more realistic approach to product development is emerging. In 2007 there were approximately 170 firms worldwide operating in this space, with commercial sales of $1500 million and

a combined capital value of listed firms of $4700 million according to Lysaght and colleagues [13 Table 1].[2] A recent survey of the RM industry found the size of the cell therapy sector has increased significantly over the last five years and was composed of 138 primary firms and 49 secondary firms at the start of 2009 [12, 101]. Primary firms were defined as those producing cell based products, while secondary firms created products that provided structural components (matrices, scaffolds and biocompatible materials) to enable cell growth. Sales of primary products (containing cells) totaled no more than $100 million a year, and combined with sales of secondary products (>$750 million a year) total industry sales remained less than $1 billion a year. Most of the industry is located in the US, with Germany and the UK occupying a distant second and third place respectively in national comparisons [12, 101].

To date relatively few products are commercially available, although it appears that the new focus of the regenerative medicine industry is no longer just research, but increasingly the translation and commercialization of RM products [14]. This development has led Mason to argue that we are seeing a new era in regenerative medicine, which he describes as Regenmed 2.0 [15]. However, this does not imply that research activities in regenerative medicine have been completed. Indeed, research in some areas has yet to produce compelling products.[3]

In this paper, we examine some of the reasons why many promising RM products have either taken a long time to reach the market or have failed after their launch. The specific context of healthcare, with its high need for public safety,

[2] Lysaght et al's data include firms that are active in tissue engineering, regenerative medicine and stem cell therapeutics. Their data set excludes not-for-profit cord blood banks, firms selling goods or services to other firms, organ or tissue allografts, conventional bone marrow transplantation, and bioaesthetic products. Private sector cord cell banking and Medtronic's INFUSE Bone Graft products, which account for a large share of current sales, were included.

[3] According to one anonymous referee the disease targets for which the industry has yet to produce a product with compelling efficacy, despite substantial investment in research, include cartilage, heart, kidney, pancreas, brain, and blood vessels.

significant regulatory content and its interaction with public opinion and ethics means that the barriers to the commercialization of RM products may be significantly different to those for previous technologies and may strongly differ between countries. The current analysis focuses on the United Kingdom and is based on the perceptions of leading industrialists in RM.

Barriers to commercialization that have been described in the literature include the cost of manufacturing and production scale up [15, 16], shipping and storage [17], lack of funding at various stages of research and development [18], and difficulties with demonstrating cost-effectiveness which lead to issues with reimbursement by healthcare providers [18]. Some of these barriers would probably not be an issue today if the industry had developed products that addressed an unmet clinical need.

Another barrier that has attracted considerable attention is the regulatory environment and uncertainty about future developments [4]. At the time of our interviews, the regulation of regenerative medicine products across the EU was fragmented and differed between each member state [19]. Many of these products are regulated as medicinal therapies, whilst others have characteristics more similar to medical devices, but cannot be regulated as such because they contain living cells [20]. Consequently, individual member states have developed national regulatory requirements [20, 21], which make it difficult for companies to simultaneously launch their products in several geographic markets. It is envisaged that such difference will be addressed by the recently adopted ATMP regulations [22] which were mandated in late 2008. However, at the time of data collection, the differences described above remained.

Do funding issues outweigh concerns about regulatory requirements? Or do issues with shipping and storage slow down the process of bringing RM products to

the market? The main objective of this paper is to investigate the barriers that leading industrialists in the UK consider to be the main impediments to the development of the regenerative medicine industry. Our arguments are based on interview data, and thus rely on the accounts given to us by respondents – all of whom worked within the regenerative medicine industry, and as such, may be considered as having a vested interest in addressing these barriers in order to enable the industry to develop and grow.

This introduction is followed by a short description of the data collection method. Part 3 of this paper describes the results of the interviews with leading industrialists in the UK and part 4 concludes the analysis by presenting a series of policy suggestions.

2 Data and methods

This paper is based on data collected during an in-depth qualitative examination of the barriers to the commercialization and utilisation of regenerative medicine.[4] Following a web-based search, representatives of companies and professional associations in the field of regenerative medicine in the UK were interviewed by telephone or in person. Respondents were asked to consent to participate in the study. They were informed that all information collected during the interview would be treated in the strictest confidence, and that all data would be stored securely according to the data protection regulations of our universities. Interviews were semi-structured, allowing for divergence from the original interview schedule based on the respondent's expertise. In total, 20 interviews were conducted, with 17 senior representatives from RM companies and 3 respondents working for professional associations and public interest

[4] Further information can be found in Rowley, E and Martin, P. (2009). *Barriers to the commericalisation and utilisation of regenerative medicine*, available to download at: www.nottingham.ac.uk/iss/regenmed

groups affiliated to the field. With the exception of two, all companies had headquarters or a branch located in the UK.

The respondents generally expressed their personal impressions and opinions, and their answers therefore do not necessarily reflect their companies' official point of view. The sample size might at first appear to be modest, but reflects the small size of the industry in the UK, which was our primary focus.[5] The overall size of the industry globally is still relatively small, with approximately 170-180 companies worldwide directly involved [12, 101, 13].

All interviews were conducted between September and December 2007 by the first two authors. The interviews were therefore conducted before recent changes in the regulatory process in the EU [22]. Each interview lasted between 40 to 120 minutes and covered questions on the current state of regenerative medicine, product development, market barriers, collaborations, future directions and policy interventions. Exemplar quotes are included for illustrative purposes. This paper focuses on the parts of the interviews that addressed competitiveness, the market, barriers to commercialization and possible policy interventions. Where possible we have anchored the interview responses in existing literature, but this is not always possible given the emerging nature of the industry.

3 Discussion

Before moving onto the specific barriers to commercialization, we address respondents' perceptions of the competitiveness of the UK regenerative medicine industry, their company's target markets and their opinion of current and future products. These evaluations provide an overview of the state of the RM industry in

[5] For example, the newly established Regenerative Medicine Industry Group (RIG), chaired by Richard Archer, is expected to have a membership of 20 UK RM companies.

general, and specifically in the UK and provide a baseline description of the industry, in which the impact of the reported barriers can be assessed.

3.1 Competitiveness of the industry in the UK

We were interested to explore how representatives of UK based regenerative medicine companies evaluate the competitiveness of the industry in the UK compared to that in other countries. Responses obviously depend on the criteria being used to assess competitiveness. For example, should competitiveness be measured in terms of volume of research, number of companies or product sales? Given the lack of an agreed measurement, answers were expectedly varied. Most respondents perceived the UK RM industry to be competitive, especially in regards to wound healing products. However, such an example of successful competitiveness was contrasted by the small number of companies, products and sales. The industry was described as being in an embryonic phase, in which a real industrial base is largely missing. For example, one respondent described

> "I don't know that we really have a regenerative medicine industry here in the UK yet, not well established, but a few small spinout companies, and companies like Smith and Nephew obviously, but I don't think we really have a base just yet" (M196).

The overwhelming consensus among respondents was that while RM science is first rank in the UK, it lags behind the USA and other countries when translating and commercializing that science. In some areas, such as human embryonic stem cells, respondents reported that the UK appears to have a scientific lead over the USA. However, many cautioned that scientific leads like this might quickly disappear if the translation and commercialization of therapies is hindered. Moreover, this may be further jeopardized following President Obama's over-ruling of the ban on Federal money being used for embryonic stem cell research in the USA.

Interviewees were asked which countries they perceived to be more competitive than the UK in RM, and to give reasons for this. Companies based in the USA were considered to be in a much better position with respect to the ability to gain external funding than those in the UK. As one respondent described:

> "I think the UK is clearly a benign environment in which to conduct this type of research. Unfortunately the critical mass and funding is such that we, I think we fall well behind, in terms of commercial exploitation of cell therapy approaches we are miles behind. I think some of the basic science is great and the work that's going on in some of the centres of excellence that we have dotted around the country and indeed elsewhere in hot spots if you like around the world, you know there's lots and lots of great basic science being done. But in terms of commercially exploiting this science and getting funding for it, you know we're just so far behind the States you know" (M172).

Countries with a dominantly private healthcare structure were thought to offer better prospects for reimbursement of RM products, as healthcare providers compete among each other and want to take advantage of the latest technology in order to attract the most patients (and subsequently, more revenue).

Although UK RM science was perceived to be world leading, it was generally noted that healthcare organisations were not equipped to take advantage of this. Respondents reported that it was difficult to get products into the clinic, with the National Health Service (NHS) traditionally being a poor adopter of innovation [23]. There were however, contrasting opinions as to whether the NHS, which dominates the healthcare market in the UK, was an important market for companies to enter. Respondents' estimates of the NHS as an entity in the world market ranged from 3-6%. Consequently, some respondents were wary about investing resources in introducing a product into such a relatively small market, and chose to launch their products elsewhere in the world with the intention of returning to the NHS at a later date.

The comparatively vast size of the American market was seen to give US-based companies an advantage over their UK based counterparts. However, it is important to recognize that companies need to have a global outlook and distribution plan if they are to be successful [24], as the UK market is too small in terms of potential sales volume. Indeed, all of the companies in our study had a global vision. Those that were currently operating in only one market did not intend to stay local in the long-term.

3.2 Target markets

Approximately half of the companies in our sample were currently marketing products worldwide. These companies had strategically targeted certain geographical markets based on ease of entry, regulatory hurdles, general company strategy or the company's administrative location. The current diversity in country-specific regulation of RM therapeutics means that a product might be classified as a medical device in one country and as a biologic in another [21]. Companies therefore chose to target markets that offered them a clear, straightforward and consistent regulatory pathway.

The USA was frequently mentioned as the most important market for companies to target because it provides a large potential customer base with one language and one administrative system. Regulators in the USA were deemed to have more experience in dealing with RM, which enabled respondents to feel that they received great clarity in the information gained. Other markets that were often targeted before the UK included other countries in Europe, Australia and Japan, although regulatory hurdles were perceived to be very high in Japan. Compared to its current position, the attractiveness of the EU as a potential market has been

anticipated to substantially increase with the harmonization of regulation [22], which was still forthcoming at the time of the interviews. However, this is unlikely to radically alter the position of the UK as a potential customer of RM, given the difficulties already discussed regarding integrating new technologies into the NHS.

3.3 Products

Thus far, the few commercial successes for the sector have been in the therapeutic areas described as "low hanging" fruit [4]. Some companies had commercialized skin, soft tissue and cartilage products. However, these products have manufacturing costs which are high compared with currently available alternative therapies. As a result, the profit margin on these products is often not high enough to justify the substantial cost of development and clinical trials.

According to our interviewees a product has a chance of reaching commercial success if there is a large enough market and the product is relatively easy to produce, or if there is a small high value market of customized goods for life threatening disorders in which there is no alternative therapy. This can be summarized as two different product strategies:

1) Mass market approach; low product price / high volume of sales.

2) Specialised market; high product price / low volume of sales.

Products that are currently on the market mostly fall into the first category. The initial focus within this category has been on products made with patient's own cells – i.e. autologous therapies. However, these products are difficult to produce at scale and commercialize as they are patient specific therapeutics. They are manufactured and are used purely in the treatment of one patient. In addition to the personalised nature of these products, other limitations identified by the respondents included:

- Issues with storage and short shelf life of products
- Long lead time for clinicians to receive products
- Lack of long-term clinical results and thus problems with product adoption and reimbursement
- High cost and the perception of value for money

One respondent described how regenerative medicine had experienced a "false start" because early companies had not adequately anticipated the costs of manufacturing and scale up, which had in turn caused problems with reimbursement. Our interviewees recognized that the arrival of a cell based product with significant sales or one that addresses an unmet clinical need would change the current lack of interest by venture capitalists and large pharmaceutical companies in RM.

Respondents reported that the products currently in development were targeting: vascular disease, damaged blood vessels, the central nervous system, cartilage, diabetes, cardiovascular system and the brain. Companies appeared to be concentrating on indications that were perceived to provide value for money and place more emphasis on evidence-based medicine. The use of allogeneic, off-the-shelf products, which are perceived to be easier to commercialize as they provide the potential for large-scale production, was considered to be the way forward for RM. Aesthetic therapies were also suggested as a valuable area for future consideration, as patients would pay for products (such as those targeting hair follicle repair) themselves.[6]

[6] As one anonymous referee pointed out, the RM industry, especially in the UK, actually often focuses on aesthetic products first to generate revenue rather than considering them as future products.

3.4 Barriers to commercialization

Table 1 lists the barriers respondents identified as the most significant impediments to the development of the RM industry.

-- Table 1 about here --

With regards to funding, it has been noted that venture capital funding was more easily available in the early stages of the industry. Venture capitalists increasingly require clinical data indicating potential success before they are willing to invest in a new company [25]. Barriers to the translation and commercialization of RM science were seen as being caused by:

1) The struggle to raise enough funds for translation, with the emergence of a typical biotechnology funding gap between basic and applied science [26]. Respondents repeatedly described how private equity investors were unwilling to fund high risk, early stage RM ventures. This was especially true when companies were using embryonic stem cells, although the UK was also seen as being leading in this area. The lack of venture capitalist (VC) interest was explained in terms of the requirement of more data before VCs were willing to invest, but that without substantial additional funding, RM companies were unable to carry out the work that would provide such data.

2) The structure of the NHS and requirements of the National Institute for Health and Clinical Excellence (NICE) were seen as huge burdens, mostly because of the considerable amount of clinical evidence required in relation to effectiveness. Respondents considered the extent of the data required to be unrealistic for start-up companies, as most in the RM industry are. In particular, the NHS / NICE

requirement that they receive the same level of evidence of efficacy for RM products as that resulting from large-scale pharmaceutical trials (for example, data on 20000 patients) was considered as a major barrier to the commercialization of regenerative medicine science. RM companies do not have access to the same levels and extent of funding support as larger scale pharmaceutical companies, and argue that as a consequence of this and the early stage of the industry, they cannot gain such data. Yet without such evidence, it is unlikely that RM products will be accepted for use in UK public healthcare.

3) Industry competitiveness was perceived to have been greatly hindered by a lack of regulatory clarity. Respondents repeatedly mentioned uncertainty about regulatory requirements and definitions, and the expected size and protocols of clinical trials.

We now present a more detailed analysis of three of the most prominent barriers mentioned by participants: regulation, research funding and reimbursement.

3.4.1 Regulation

The majority of respondents indicated that their company employed a person or a team dedicated to dealing with regulation matters. Given that the majority of respondents worked in SMEs with small workforces, the decision to employ a regulatory specialist demonstrates companies' acknowledgement of this difficult area for the industry. This in-house expertise was often supplemented by hiring outside consultants and distributors were sometimes asked to assist with country-specific requirements.

Interviewees perceived the regulatory process to be very problematic, especially if the company was the first to develop a specific therapy that did not

clearly fall into a specific category [21]. This often resulted in individuals believing that their company wasted a considerable amount of time and money on gathering the wrong type of data (as defined by the regulators). In such cases, interviewees considered the regulators were often too inexperienced in dealing with RM technologies and were likely to change their mind about what evidence should be provided by the company, before approval could be received.

Regulatory clarity is of utmost importance for companies to keep development and production costs low and timelines short. Most respondents found regulators to be very approachable and co-operated with companies to help bring products to the market, whilst at the same time carrying out their responsibility for ethical oversight. This was particularly resonant in areas such as stem cell research in which political pressure has been exerted to ensure that the UK maintains its lead in this field. Given the USA's greater market for RM products, it was of no surprise that respondents consider US regulators to be more experienced in dealing with RM technologies than those in other countries. Some respondents stated that regulators should have more direct discussions with industry, as evidence suggests that regulatory uncertainty is one of the main reasons why investors are reluctant to invest in RM.

The harmonization of regulation in EU countries was eagerly awaited by some, although for others, this development was greeted in a more sceptical light. It was expected that regulators' current lack of understanding of these products would improve overall. However, some new regulatory requirements, such as the "constant monitoring" of a product, would be almost impossible to comply with. These uncertainties add to the existing difficult regulatory environment that RM companies face.

Respondents repeatedly expressed the need for a clear regulatory framework, arguing that even if regulatory requirements were difficult to meet, the industry will be in a more advantageous position once it knows what to expect. As companies already face considerable uncertainty about the development of the technology, involvement of stakeholders and getting products adopted by the market, clarity in terms of regulation was highly anticipated. In a promising move in advance of the ATMP regulations coming into force, some participants indicated that the regulatory situation was already improving [27].

3.4.2 Reimbursement process

Given the embryonic nature of the RM industry, only a few of the individuals interviewed had dealt with the reimbursement process. However, the majority of respondents recognised the lack of a reimbursement pathway as a considerable problem. This led to secondary problems. Investors, unsurprisingly, were reported as not wanting to invest in a company that had uncertain product sales. It was suggested that one way in which companies might overcome this barrier was to perform economic modelling early on in the product development phase to establish what sort of clinical benefit would sustain a product marketed at a certain price [28]. Indeed, most of the companies that did not have products on the market at the point of the interview mentioned that they try to address reimbursement issues early on by keeping prices low. Secondly, in the UK, if a product is not included within the NHS tariff, it is highly unlikely to be used due to rules on co-payment. The only options to increase product use remain providing the therapy free-of-charge for use in clinical trials, or for use in private healthcare.

In contrast to the USA where commercial pressures have the potential to drive the field forward, a significant market 'pull' is missing in the UK industry. Due to state control and funding of healthcare, hospitals and surgeons do not routinely compete with one another to recruit patients into their care, and so have less incentive to advertise that they use the latest technologies. In the UK, reimbursement is handled differently in every NHS Trust, and based on the experiences of other medical devices and pharmaceuticals, is likely to be highly variable. Respondents recognised the NHS to be risk-adverse and conservative in its choice of tariffed products. Given this, it was felt that for RM products to be used, not only must they achieve an improved outcome compared to existing products, they must also be financially attractive. As one respondent explained:

> "It could still be difficult to get an acceptance if for example at point of purchase, the choice for the purchasing authority is between a simple dressing for a conservative therapy and something a lot more complex, they will normally go for the simple dressing even if the whole course of therapy is more expensive for the organisation" (M195).

The structure of the NHS (as an organisation) was seen to be problematic, as was that of NICE. Both were described as 'monolithic' and as presenting a huge hurdle to the introduction of clinically relevant innovative products. Consequently, it was felt that getting innovation into the NHS would require structural, organisational and cultural change, as well as product specific results in terms of cost, ease of use and efficacy.

NICE evaluations were repeatedly reported as being a significant barrier, with individuals perceiving the outcomes of these evaluations to be quite unpredictable. One of the problems of the cost-effectiveness model employed in the UK is that the system has difficulties with accepting high up-front costs. For RM, whilst the up-front costs of therapies are high, in the long-term, they could be substantially lower compared to the costs involved in utilising the current gold standard treatment. For

example, the treatment of a diabetic foot ulcer using RM products will run into tens of thousands of (US) dollars, compared to the minimal costs incurred using conventional therapeutic options [29]. Hüsing et al. [30] found that RM skin cost €9.92 to €20.85 per cm^2, whilst conventional treatments costs between €0.37 and €8.66 per cm^2. However, RM therapies would be used in a shorter treatment period, meaning less resources will be used in terms of length of hospital stay, nursing time, and dressings. This price differential is compounded by the division of health funding. To continue with the example of wound healing, a conventional (non-RM) therapy might involve continuous treatment over the course of a year or more. Following an initial in-patient stay, the majority of the costs involved in the patient's treatment will be incurred by the community healthcare provider. Consequently, the cost savings received as a result of the RM treatment would not be incurred by the acute sector, although under current funding models, it would be this sector that had to pay for the treatment. Rather, the long-term cost savings resulting from the use of a RM product, would be received by the community sector. This observation was termed 'short termism' by one respondent:

> "There's a lot of shortism, short termism in terms of that so, and that is a big problem for us in terms of some of these rule changes in treatment paradigm because you know the provider hospital is only interested in the three month period under which they have liability for the procedure. As soon as it comes out of that actually they don't mind if the patient comes back, they get paid again." (M169).

The majority of respondents remarked that one of the main barriers to reimbursement is the development of sufficient cost-benefit and efficacy evidence. NICE does not recalibrate its trial size requirements for innovative therapies, but rather insists that biotech innovations such as RM, should have their effectiveness measured in a comparable manner to pharmaceutics. However, as discussed earlier, given the

difficulties that the RM industry report that they face in gaining sufficient funding, respondents argued that they are unable to provide this level of evidence.[7]

Given these difficulties, some companies had opted to follow a business strategy whereby some products would be reimbursable and used in public healthcare while others, mostly bio-aesthetic applications, would be paid for directly by patients. Whilst such a move ensures that products are able to enter the market, it also results in a division of RM technologies, between the high-science therapeutic areas that public healthcare will pay for, and therapies, such as hair regeneration or wrinkle treatment (for instance, ICX-TRC and Vavelta by Intercytex) that are likely to become popular and used in elective cosmetic surgery.

3.4.3 Funding

Respondents indicated that their companies had received investment from various sources, including:

- Seed funding (university start up)
- DTI grants (in collaboration with academic partners)
- VC funding
- Research councils and charities (prior to university spin out)
- Internal funding (in the case of large companies)
- Philanthropists (personal donations)

The source of funding that a company relied on often depended on the company's stage of development. A minority of companies had gone public and been listed on the stock exchange, meaning that they were able to 'tap the market' for additional

[7] As one anonymous referee pointed out, other issues for conducting clinical trials of cell based products include the lack of double blinded studies and patient acceptance.

funding. The ease of obtaining funding was experienced very differently, with individuals reporting variable experiences. While some suffered from the typical biotech funding gap between academic seed core funding and a series B funding round, others encountered considerable interest from high-risk investors. On balance, however, difficulties with raising funds appear to be a common problem.

> "Funding is a significant problem for the industry because there are, there are, most of the companies, well most companies that have, that are in the field are now actually publicly quoted companies and that's the major way that this sort of work gets funded. Venture Capital won't touch it or very rarely touch this sort of thing. And part of the problem that VCs have is that they can't really value early stage technologies and in fact they look at companies that do, that are on the public market, there aren't any sort of really, I mean apart from the couple in the US there are aren't any real, really highly valued companies" (M179).

The perception that investors were reluctant to enter the field because of the uncertainty of reimbursement and long timelines in the development and utilisation of products was repeatedly mentioned. It was explained that because the industry was still in its infancy, it was difficult for investors to estimate the risk, given how the field had been damaged by the initial hype (for example, the suggestion that a fully-formed organ would be grown in a Petri dish, or that RM would become a global market of $2 billion p.a. by the year 2000 [8]). Moreover, it was reported that investors were unsure about the exit strategies of the smaller RM companies, and were hesitant until future strategic development plans had been solidified. For example, would companies go public and be listed on the stock exchange? Would they be acquired by large pharmaceutical companies? When would profit be generated from product sales?[8]

[8] One of the anonymous reviewers emphasized that the rate of spend increases as a product/company develops. While $1 million of seed funding from a University may be sufficient for a small company, this company will eventually grow into a larger company with a potential burn rate in excess of $20 million a year and over a hundred employees. Companies often do not have a real strategy to maintain adequate funding levels while progressing to market.

3.5 Policies

Given the barriers to the development of the RM industry and investors' apparent reluctance to invest, government intervention seems necessary given the current uncertainties about the commercial viability of products [31]. Interviewees were asked to suggest what policy recommendations they would welcome (Table 2).

-- Table 2 about here --

With regards to funding, several respondents stated that while they had benefited from DTI grants and research council funding, there was a need for greater government support in order to strengthen and promote the industry and UK science. Many respondents pointed to what they perceived to be the failure of the UK Stem Cell Foundation to divert funds to the RM community. Although government agencies (such as the MHRA) were reported to be in discussion with companies, it was suggested that there was not enough money behind such initiatives. This finding is not unique to this present study. Nerem recommends increased research funding and government support, as well as improved regulatory structures for innovative products and improved reimbursement processes [8].

4 Conclusion

Qualitative interviews with 20 representatives from the regenerative medicine industry and interest groups revealed that scientific research on regenerative medicine is thriving in the UK. Unfortunately, lack of access to capital, regulatory hurdles, lack of clinical evidence leading to problems with reimbursement, as well as the structure and culture of the NHS do not provide a good environment for the commercialization

of RM products. It is unclear whether the barriers reported by the RM companies are consistent with other emerging industries, but Mason notes that some problems of the early RM industry are reminiscent of the barriers encountered by the early internet entrepreneurs, including scale up, lack of experienced people and lack of business models [15]. All these barriers to commercialization might be quickly overcome once the industry develops products that address a need that has not yet been met by existing products and start to generate large sales on this basis.

Policy interventions, such as providing more translational government funding, a restructuring of the NHS and NICE as well regulatory clarity were considered to likely improve the general outcomes for the industry in the UK. Lack of funding was most frequently mentioned to be a barrier to commercialization and, not surprisingly, was also the focus of policy recommendations. Access to funding appears to be a barrier specific to the RM industry and should therefore be addressed by government policy to allow this promising field to succeed. In addition to direct government funding, policy interventions could provide incentives for investment, for instance by creating tax exemptions for those who invest in innovative therapies.

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Table 1: Most significant barriers to commercialization

Barrier
Access to capital, finance
Distribution channels, logistics
Access to skilled human capital
Scientific barrier, products that work
Cost, cost effectiveness proof
Regulatory requirements, lack of clarity
Clinical validation, evidence, data
Clinicians' acceptance, adoption despite absence of long-term data
Reimbursement
NHS culture
Marketing channels
Scale up

Table 2: Policy recommendations suggested by survey respondents

Policy recommendation
Better provisions for translational funding, funding in general
Special NHS funds for innovative treatments, encourage product adoption
Transparent regulatory environment, speed up regulatory process
Changes in NICE, facilitate reimbursement, more transparency of NICE evaluations
More networking in RM industry, promote research collaborations
Tax exemptions for people who invest in stem cells, innovative therapies; encourage investors somehow
Financial incentives, like tax breaks
Educational strategies that produce more skilled people
Policies to help academic and clinicians start ventures
Improve manufacturing
Simplify process of applying for grants, soft money
Better linkage to the clinical sector (NHS)
Government think tank that could advice on ethics, science and direction

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