Social Science & Medicine 174 (2017) 70–78

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Promissory identities: Sociotechnical representations & innovation in regenerative medicine

John Gardner [a, *], Ruchi Higham [a], Alex Faulkner [b], Andrew Webster [a]

[a] Science and Technology Studies Unit, Department of Sociology University of York, Heslington, York, YO10 5DD United Kingdom
[b] Centre for Global Health Policy, University of Sussex, Falmer Brighton, BN1 9RH, United Kingdom

ARTICLE INFO

Article history:
Received 26 April 2016
Received in revised form
4 December 2016
Accepted 12 December 2016
Available online 13 December 2016

Keywords:
United Kingdom
Innovation
Cell therapies
Regenerative medicine
Science and technology studies

ABSTRACT

The field of regenerative medicine (RM) is championed as a potential source of curative treatments and economic wealth, and initiatives have been launched in several countries to facilitate innovation within the field. As a way of examining the social dimensions of innovation within regenerative medicine, this paper explores the sociotechnical representations of RM technologies in the UK, and the tensions, affordances and complexities these representations present for actors within the field. Specifically, the paper uses the Science and Technology Studies-inspired notions of 'technology identity' and 'development space' to examine how particular technologies are framed and positioned by actors, and how these positionings subsequently shape innovation pathways. Four developing RM technologies are used as case studies: bioengineered tracheas; autologous chondrocyte implantation; T-cell therapies; and a 'point-of-care' cell preparation device. Using these case studies we argue that there are particular identity aspects that have powerful performative effects and provide momentum to innovation projects, and we argue that there are particular stakeholders in the UK RM landscape who appear to have considerable power in shaping these technology identities and thus innovation pathways.

1. Introduction

Innovation in healthcare has become the subject of considerable critical attention in many industrialised countries. Within political and policy discourse, medical innovation is framed as providing improved clinical outcomes and generating economic wealth, but also as a problematic, complex process hindered by institutional, regulatory and cultural constraints. This narrative is particularly strong in the emerging field of regenerative medicine (RM), which entails the use of cells, tissues or genetically-edited elements as therapeutic agents. RM is championed as a potential source of curative treatments for a wide range of ailments, and it has been identified by governments as part of their economic growth strategies: the UK has identified RM as one of 'eight great technologies' which has the potential to become the basis of a high-wealth, knowledge-based economy (Willetts, 2013). Initiatives have been launched to identify innovation challenges within RM, and to devise strategies for managing these (Department for Business Innovation and Skills, 2011; UK Research Councils, 2012; Regenerative Medicine Expert Group, 2015; House of Lords Science and Technology Committee, 2013). The perceived challenges identified include: bureaucratic research governance frameworks and inflexible clinical trial methodologies; a complex and inconsistent EU-level regulatory framework; manufacturing and scale-up of live-tissue production; uncertainties over cost-effectiveness and reimbursement; the implementation of potentially disruptive systems within busy, resource-strained clinical contexts; and a lack of investment from private funders (Gardner et al., 2015). Indeed, commentators have suggested that the emerging RM field is to some degree incommensurable with the current healthcare system and governance structures that have emerged to accommodate drug and device-based therapies (Omidvar et al., 2014).

In this paper, we explore the social and cultural dimensions of innovation within the emerging field of RM, focusing predominately on developments in the UK. Specifically, we examine the sociotechnical representations and positionings of RM technologies to interrogate the tensions, affordances and complexities of innovation in the field. To do so, we draw on and adapt Science and

* Corresponding author.
E-mail addresses: john.gardner@york.ac.uk (J. Gardner), rh955@york.ac.uk (R. Higham), A.Faulkner@sussex.ac.uk (A. Faulkner), andrew.webster@york.ac.uk (A. Webster).

http://dx.doi.org/10.1016/j.socscimed.2016.12.018

Technology Studies (STS) -inspired concepts of *technology identity* and *adoption space* (Tomlin et al., 2013; Peirce et al., 2015; Ulucanlar et al., 2013). The advantage of this framework is that it brings to light the mutually configuring relationship between a technology and actors in a specific sociotechnical context, and the effect that this has on the technology's ongoing development. It enables us to examine how RM technologies are understood by those in the field in terms of perceived challenges, affordances and expectations, and thus how innovation pathways are collectively negotiated. We use these analytical concepts to explore four developing RM technologies: bioengineered tracheas; autologous chondrocyte implantation (ACI); T-cell therapies; and a 'point-of-care' cell preparation device. Using these case studies we will show that there are particular identity aspects that have powerful performative effects and provide momentum to innovation projects, and we argue that there are particular stakeholders in the RM landscape who appear to have considerable power in shaping these technology identities and thus innovation pathways.

2. Innovation, technology, and identity

Technology identity and *adoption space*, as conceptualised by Tomlin and colleagues (Tomlin et al., 2013), have their theoretical foundations in sociology and in Science and Technology Studies (STS). To introduce these concepts, we provide a summary of some key theoretical tenets of these fields (and STS in particular) as they relate to the study of innovation.

The most important of these tenets is *relationality*. According to this, the meaning of an entity (whether it be a molecule, a technology, or social organisation) is not the result of its inner 'essence'; rather, it is a consequence of its immersion within networks of other technologies and systems of meaning making. These networks render entities intelligible by foregrounding certain potentialities (or what DeLanda (2006) has called capacities for interaction) and endowing them with meaning, while eliding other potentialities (Latour and Woolgar, 1986). In effect, then, the intelligibility of an entity such as a healthcare technology depends on the context within which it is immersed, and the same entity may be thus rendered intelligible in multiple ways. Hence, the second tenet is an acceptance of *multiplicity*: co-existing socio-technical networks may produce divergent renderings, sometimes in tension with one another (Mol, 2002; Pollock and Williams, 2010). Third, the definition of what constitutes an *'actor' does not exclude non-human entities*. A healthcare technology, for example, can be said to have agency in that it prompts, guides, constraints and transmutes the action of other entities including human agents (Latour, 2005). This is not to say that such entities determine the action of others; rather, an entity possesses affordances for further action, along with *interpretive flexibility* (Pinch and Bijker, 1984) - the fourth tenet. This means that precisely how an entity such as a healthcare technology prompts action will depend on the local meanings within which it is immersed. Combined, these tenets characterise the world as being constituted by heterogeneous material and discursive networks which produce and reproduce various kinds actors: technologies, individuals, social groups, and so on (Law, 2008).

The concepts of technology identity and adoption space reflect these key tenets. In their study of medical device adoption in healthcare, Tomlin and colleagues argued that technologies acquire particular identities that shape their adoption and dissemination (Tomlin et al., 2013; Ulucanlar et al., 2013). Technology identities are heuristic narratives; they are, as Ulucanlar and colleagues define them:

> A narrative or discursive presence of the technology that delineates a particular set of attributed characteristics and performative expectancies as representative of the technology's distinctiveness and value (2013, 98).

Identities are forged and contested within what Tomlin et al. (2013) define as the *adoption space*: the institutional context and socio-political environment within which the technology is mobilised. The former is composed of socio-technical infrastructures including technologies and tools, protocols, professional interests and institutional strategies, while the latter is composed of, for example, media coverage, public attitudes, and political discourses. Collectively, these elements imbue a technology with identity attributes; they render it intelligible as being, say, 'revolutionary', 'cost-effective', 'difficult to use' or 'implausible', by foregrounding some attributes of the technology while eliding others. Adoption spaces are also dynamic: a new policy initiative, the emergence of competing technology or some other contextual change may radically affect a technology's identity. Importantly, these identities inform decision-making processes regarding the adoption of the technology in clinical contexts: they shape "perceptions in ways that are instrumental in decisions about its use" (Ulucanlar et al., 2013, 98).

We believe that with some minor adjustment, this framework can provide a fruitful analytical vehicle for exploring healthcare technologies that are still being developed. As the sociology of expectations literature has made clear, the 'momentum' of innovation is often the result of promissory, future-orientated representations which function to align diverse interests (Borup et al., 2006). This has certainly been the case with RM (Morrison, 2012; Oerlemans et al., 2014; Gardner and Webster, 2016), characterised by high expectations but no widely-implemented routine therapeutic technologies. We suggest that emerging RM technologies inhabit a *development space*, conceptually complementary with the notion of adoption space, but likely to include the characterisation and positioning of novel technologies in anticipation of their adoption in a clinical setting. It can be defined using a slightly adjusted (in italics) definition of adoption space (Ulucanlar et al., 2013, 98):

> A spatial and temporal space transcending organisational and geographic boundaries and populated by human and non-human actors from different social worlds, where attitudes, practices, interactions and events, together with the *developing* technology's material features, shape technology perceptions in ways that are instrumental in decisions about its *further development and* use.

In this paper, we apply this analytical frame based on *technology identities* and *development spaces* to interrogate four case-study RM technologies and techniques. These are case studies which have what can be described as promissory identities: considerable (although not uncontested) high expectation surrounds their envisaged potential.

The case studies are paradigmatic of emerging areas within RM: they inhabit a field that is rich with 'matters of concern' (Latour, 2005), including, for example: the safety of therapeutic cells; the acceptable level of uncertainty regarding clinical effectiveness, safety, and cost effectiveness; and a concern that the promise of RM will fail to materialise. Development spaces potentially include the various bodies that have emerged to address such concerns (for instance cell and tissue banks, and innovation accelerator agencies), as well as pre-existing actors within the healthcare landscape (regulatory agencies such as the European Medicines Agency, patient charities, professional associations, hospitals, health technology assessment bodies, and the media). RM

technologies – such as the four examined here – are subject to considerable speculation, assessment and forecasting, as stakeholders attempt to reconcile conflicting values and establish viable development pathways. We provide a detailed discussion of how new technologies open up different spaces and pathways in the biomedical economy. We identify those actors involved in the problematisation (Callon, 1986) of the technology; that is, those who are influential in defining the obstacles and affordances of a technology to which subsequent actors must orient themselves.

3. Methods

Data for this paper were collected as part of the ESRC-funded REGenableMED project. Around 70 semi-structured interviews were conducted with scientists, clinicians, hospital managers, regulators, economists, lawyers, patient advocacy and charity representatives, professional associations, and company representatives. The interviews explored respondents' perspectives on the RM field, particularly in regard to innovation challenges, and transcripts were systematically coded using NVivo9 software to identify common themes. Various forms of publicly-available secondary data were also examined, including company reports, meeting minutes and media coverage. Data collection (including selection and recruitment of participants) and analysis have been informed by the project's Advisory Group, which includes representatives from various stakeholder groups in the UK, including companies, patient charities, accelerator agencies and the NHS. Ethics approval for data collection was obtained from the appropriate institutional ethics review board, and informed consent was obtained from all participants.

The RM field is composed of an array of developments, which can vary according to target indication, nature of the technology platform (such as cell or tissue type), developmental stage, mode of manufacturing, whether it is clinician-driven or commercially-driven, and regulatory status. In light of these considerations, and informed by an analysis of initial interview data, we produced a list of eight possible technologies that represent emerging areas. With the assistance of the Advisory Group, this list was narrowed to the four selected case studies which are paradigmatic of different development paths. Further interviews were conducted in these four areas to secure a set of views on each that is as comprehensive as possible.

While analysing the data, we drew on Ulucanlar and colleagues' (2013) taxonomy of general *technology identity dimensions*. These include: 1) the *biography* of the technology: narratives about its plausibility and clinical rationale for its use, scope, and novelty, and how these relate to its anticipated future; 2) the perceived clinical and cost *effectiveness* of the technology; 3) the perceived *utility* of the technology to advance clinical, professional or institutional aims; and 4) the perceived *risks* of the technology as they relate to clinical, financial or organisational aspects. In the following section we provide a brief overview of each technology, noting key actors within the development space. We then discuss in more depth several technology identity characteristics, as they relate to this taxonomy, which appeared to be particularly influential.

4. Findings

4.1. Bioengineered trachea

The bioengineered trachea is intended to replace severely diseased or damaged trachea segments. It is being developed in the UK by the Inspire Consortium which includes Videregen, a small commercial enterprise; the NHS Blood and Transplant Service (NHSBT), the Cell and Gene Therapy Catapult (CGTC), and scientists and surgeons from two London hospitals. The trachea is constructed from a cadaveric donor trachea (obtained by the NHSBT), which is stripped of its cells using Videregen's decellularisation technology platform, leaving a collagen scaffold. This is reseeded with the recipient's bone marrow-derived mesenchymal stem cells (which, ideally, form tracheal tissue) before being implanted. It has been used in 'compassionate-use' cases: a 30 year-old women in Spain in 2008, and a ten year-old boy in London in 2010. The technology has been subject to significant media coverage, particularly around the two recipients who have been described in some media as 'doing well'. A Phase I clinical trial, sponsored by the CGTC, is due to start soon in the UK, and as part of a larger EU consortium, the project has been awarded a Horizon 2020 grant for Phase II clinical trials.

Our analysis of the portrayal of trachea identity dimensions suggests that the key actors in the development space include clinical innovators ('champions') and their institutions, news media, and the CGTC. One particularly influential identity aspect is its perceived plausibility for *addressing a severe unmet clinical need*. This is expressed in the rationale of one of the consortium's surgeons for becoming involved:

> It was clear very early that the ways we had available to reconstruct people after major head and neck surgery [for cancer] were okay but left huge functional deficits and there were some things we simply couldn't reconstruct, such as the larynx and the trachea. (Consortium Surgeon)

This identity attribute has influenced the innovation pathway, in that it provided a rationale for securing regulatory approval and institutional support for the compassionate use cases:

> Initial experiments were encouraging and so presented with a sick lady in 2008 who had exhausted conventional options, we got permission from the Spanish Health Ministry and interestingly the Human Tissues Authority in the UK … Regulation authorities were approached and approved. (Consortium Surgeon)

> We were presented with a boy who had a terrible trachea problem … he was at death's door and his tracheal stent had eroded into his aorta … [since the implantation] he's done very well … [it's] certainly not ideal, but it saved his life. (Consortium Surgeon)

The trachea has thus acquired a biography as a *lifesaving* technology, justifying its use despite some complications. This has provided important affordances for the consortium: gatekeeping actors (such as the Spanish Health Ministry and the UK's Medicines and Healthcare Products Regulatory Agency) have reified this biography by permitting in-human use on compassionate grounds, and this has enabled the consortium to gather information to inform upcoming clinical trials (Surgeon, Interview). Influential actors within the development space, particularly the surgeons' host institutions and news media, have also framed the consortium's trachea as 'lifesaving' (e.g. "desperate attempt to save his life after other treatments failed …" (Daily Mail Reporter, 2012).

Additionally, these actors also frame the trachea as part of a 'breakthrough' (Roberts, 2008) or 'pioneering' (Adams, 2012) *transplantation* procedure, conducted by a *transplant team* at elite UK hospitals. This explicit framing links the success of the construct to the reputation of the hospital and the surgical team – a link which, according to a Videregen representative, has facilitated the subsequent development of the trachea project:

> We've got Professor [surgeon] who's the leading clinician … he's a world leader so having him on the project … was a great

clinical endorsement. That has enabled us to move, to get to places we wouldn't normally get to. (Videregen Rep1)

The reputation of the clinicians, then, contributes to the promissory power of the trachea identity, and at the same time, the reputation of host institutions as pioneers in regenerative medicine is enhanced.

The 'transplantation' framing, with connotations of both 'risk' and 'lifesaving' is drawn upon by clinicians and scientists themselves. Here, a scientist involved in the trachea development recounts a conversation between himself and other clinicians:

A cardiac transplant surgeon said [to another surgeon] have you any idea how many heart transplants we did before the first one worked? If anyone had said "I've only done two of these and 50% of them died" I'm not going to do another one" it would never have happened.

So the present-day high risk of the trachea transplantation procedure is justified by the promise of a lower-risk future. This framing supports a further aspect of the trachea's biography, namely that it represents a *gateway* to a world of bespoke organ generation:

"[This is] a demonstration project for us really to then show that the technology platform works. We can then develop much more complicated products to take forward.

The technique has thus acquired an influential biography as being part of a *lifesaving* procedure, and as a testing and development platform or *gateway* to bespoke organ generation. These dual identity attributes appear to be providing significant momentum by aligning disparate actors within the development space: regulators, 'highly reputable' surgeons, commercial interests, and the CGTC.

The trachea identity attributes recursively provide affordances for other actors in the development space: for example, the consortium's project appears to have an important strategic *utility* for the CGTC. CGTC's stated rationale for their involvement refers to the considerable potential ("estimated to be US $600 million per year"), and to the innovativeness of the project as a whole: "pathfinding complex 3D manufacture and business models" (CGTC, 2014, 6). The promissory biography of the trachea, in other words, aligns with the national industrial strategy for generating 'health and wealth'. Importantly, this involvement in the trachea project is seen by other partners as an endorsement which has led to further funding (Videregen Rep1, Interview), including a substantial Horizon 2020 grant for Phase II trials.

Nevertheless, despite the power of the trachea identity, the plausibility and 'lifesaving' aspects are being contested. A scandal has embroiled surgeon Paolo Macchiarini, who has allegedly severely misrepresented the poor clinical outcomes of patients who received a synthetic trachea construct in Sweden and elsewhere. Macchiarini and his host institution (the Karolinska Institute) had been the subject of criticism from Pierre Delaere, professor of respiratory surgery at KU Leuven. Delaere has also criticised the Inspire Consortium's project: the crux of his criticisms is that the reseeded cells fail to sufficiently regenerate into vascularised tissue, and that any therapeutic benefit derives from the stent that is used to maintain an open airway (Delaere, 2010; Delaere and Van Raemdonck, 2014). Some online science bloggers have adopted Delaere's stance and are highly critical of the decellularised trachea (e.g. Schneider, 2016). It remains to be seen if these contrasting representations of the Consortium's bioengineered trachea will gain momentum and undermine the affordances being built elsewhere.

4.2. ACI: MACI/ChondroCelect/the OsCell method

ACI refers to a group of therapies for repairing cartilage damage of the knee. Chondrocytes are extracted from the knee of the patient, expanded ex vivo, and then replanted into the damaged area. Specific ACI therapies differ according to the duration of ex-vivo expansion, and the means of re-administration. Two ACI techniques have been commercialised: MACI (currently manufactured by Aastrom) and ChondroCelect (developed by Tigenix). These are two of the few RM products to have received marketing authorisation from the European Medicines Agency under the Advanced Therapy Medicinal Products (ATMP) regulatory framework. However, ACI has not been widely adopted due to difficulties securing reimbursement arrangements: National Health Technology Assessment agencies in France and the UK have stated that as yet there is insufficient evidence, and in mid-2016 Chondrocelect was withdrawn from the market. In the UK, an additional ACI technique, what we can call the 'OsCell method', has been developed within a specialist clinical site, and is manufactured under a special 'hospital exemption' licence (see Mahalatchimy et al., 2012).

The development space of these therapies includes professional associations such as the British Orthopaedic Research Association (BORS) and the British Association for Surgery of the Knee, and particular Health Technology Assessment agencies such as the UK's National Institute for Health and Care Excellence (NICE).

For clinical champions, an important aspect of the ACI biography is its designation as *a 'regenerative' or 'cell-based' therapy*. Interviewees working within orthopaedics suggest that ACI represents a progressive step towards what they felt was the future of bone and cartilage repair:

… metallic implants like total hip replacements and total knee replacements are sort of done and dusted … optimized but they haven't solved all of the problems. I think the only way to solve those problems is to go to the biology of the system, and for that reason, I think regenerative medicine is really important (BORS rep1, Interview)

A recent editorial (McCaskie, 2015) in *The Bone & Joint Journal* also makes this point, and the research charity Arthritis UK has adopted this position, hence its funding of the UK Tissue Engineering Centre. There is, then, some promissory momentum behind RM within the orthopaedic field, and ACI is broadly associated with this.

Another identity aspect of ACI relates to its perceived clinical utility. Among orthopaedic clinicians ACI is seen as *clinically useful and appropriate* for specific indications, but *not a remarkable or exceptional treatment*. This is illustrated by the recent UK knee surgeons' consensus statement on management of articular cartilage defects of the knee (Biant et al., 2015). The statement argues that:

For lesions 2–4 cm^2 in the average sized knee, [ACI] is the most effective treatment option based on the published literature … Lesions > 4cm2 … studies suggest that cell therapy is the best evidence-based treatment in this situation.

It adds that conventional therapies are more appropriate for lesions of other sizes, and that available evidence suggests that for some outcome measures, there is no difference between ACI and conventional therapies at five years after treatment. Such

statements frame ACI as an important part of the clinical repertoire, but certainly not – currently - a radical improvement over other options.

The consensus statement illustrates a wider tension concerning the *clinical effectiveness* identity dimension of ACI. Evidence of clinical effectiveness was deemed sufficient by the European Medicines Agency to demonstrate that the "benefits are greater than its risks". The EMA also stated, however, that "knowledge of the long-term effect of the medicine is limited" (EMA, 2014, 3). This has been emphasised by other gatekeeping actors, and ACI has obtained a potentially influential *uncertain long-term effectiveness* identity aspect as a result. The significance and implications of this identity aspect differ across healthcare contexts. In the UK, it was consolidated in a recent, publicly available, NICE cost assessment (NICE, 2015). A positive recommendation would have led to nationwide commissioning in England. However, based on an appraisal of current evidence of ChondroCelect, MACI and the OsCell method, the draft guidance states that ACI "is recommended only in research". The findings state that data on clinical effectiveness were heterogeneous and of mixed quality, some of which was poor quality due to "small sample sizes" and "inadequate durations of follow-up". Similarly, long term cost-effectiveness of ACI was uncertain as "each study lacked long-term clinical follow-up data and good quality of life data" (NICE, 2015, 18). The British Association for Surgery of the Knee has expressed its disappointment in the draft assessment and is encouraging ACI recipients to submit comments in support of ACI to NICE (BASK, 2015).

Within the UK, then, this *uncertain long term effectiveness* identity of ACI has hindered its dissemination in the NHS. The emphasis placed on this identity aspect differs among actors within the development space. Health insurance companies, for example, had agreed to fund ChondroCelect for private patients in the UK. Gatekeeping actors in other health jurisdictions have also foregrounded other identity aspects: in the Netherlands, for example, the promissory value of ACI as an RM was reflected in the inclusion of ChondroCelect on a special reimbursement scheme ("Beleidsregel Dure Geneesmiddelen") for innovative medical technologies. Nevertheless, the uncertain long term effectiveness identity dimension has, recursively, had a significant effect on companies involved in ACI: due to the inability to secure widespread reimbursement for their product, TiGenix initiated the withdrawal of their product from marketing authorisation for 'commercial reasons', and is instead focusing on a different RM technology platform to "deliver shareholder value" (Globe Newswire, 2016).

What we see here, then, is that ACI has been endowed with a complex identity by various actors: it has some promissory value, but it is not considered to be particularly radical. It is considered useful and appropriate for some indications, but its long-term clinical effect is uncertain. The emphasis placed on each of these aspects differs among various decision-making actors within the development space, meaning that ACI techniques have been nationally reimbursed in some countries but not others.

4.3. CAR T-Cells

Chimeric Antigen Receptor, or 'CAR', T-Cell therapies are immunotherapies that treat cancer. Donor (allogeneic) or recipient (autologous) T-Cells are isolated and genetically reprogrammed to recognize malignant cells, triggering a targeted immune response. Promising recent results have generated considerable interest in the area (Vertes, 2016), and in the UK it was used as an exemplar to test the suitability of NICE's technology appraisal methodology for assessing RM treatments. Worldwide there are dozens of clinical trials testing CAR T-Cells, mostly for blood cancers, but also for glioma, glioblastoma, and other head and neck cancers. Many are sponsored by small companies working in conjunction with research-intensive hospitals, although recently large pharmaceutical companies have also become involved.

The development space for CAR T-Cell therapies is thus constituted by a range of actors including clinicians and their research hospitals, SMEs, big pharma, and the media. Additionally, an important feature of the development space is the biomedical infrastructure that has emerged to diagnose and manage blood cancers and autoimmune conditions, much of which is managed by NHSBT (in the UK) and Haematological services. This infrastructure has provided a structuring platform for further innovation (Keating and Cambrosio, 2003), and this is reflected in the emergence of T-Cell immunotherapies: NHSBT, for example, has established a Stem Cell and Immunotherapy Research Unit with University College London. One consequence is that subpopulations of T-Cells can be relatively easily isolated, identified and quantified using existing processes. As one interviewee noted:

> You can grow them up to a precise number, more or less anyway, and then you can also follow them in the patient. And you can follow the different … sub-sets, and you can also characterise the different sub-sets, in the lab and in the patient … (Researcher/Clinician, Interview).

Thus among some actors, CAR T-Cells have acquired an identity as being *delineable* and thus *monitorable* – characteristics that relate to their risk identity dimension, which are important also for designing protocols for clinical studies, particularly for monitoring safety.

The technology's biography is dominated by 'remarkable' results of early clinical studies, generating considerable enthusiasm. Here, a clinician reflects on recent clinical studies for ALL:

> We're talking about patients with terminal [acute lymphoblastic leukaemia] for whom there is no treatment … Phase 1 clinical trials with an 80% complete response rate, achieving complete sustained clinical remission … I've never seen anything like it in my life … normally, a new agent in a Phase 1, if you get a 10% response rate that's probably as good as it gets. (Clinician, Interview)

As with the bioengineered trachea, CAR T-Cell technology has acquired a biography as a *lifesaving* technology. This aspect has been reinforced by other actors within the development space, particularly the media. One commentary noted:

> "Among several dozen patients who would typically have only had months to live, early experimental trials that use the immune system's T-Cells to target cancers had 'extraordinary results'. In one study, 94% of participants with [acute lymphoblastic leukaemia] saw their symptoms completely vanish" (Yuhas, 2016).

Another article, which covers the case of a young child, states:

> "Layla Richards had one of the worst cases of leukaemia her doctors had ever seen and, when all other treatments failed, her parents were told to expect the worst … thanks to an infusion of 50 million cells genetically engineered to hunt and kill the cancer, the disease has vanished and she is happy …" (MacRae, 2015)

These quotes also highlight another key aspect of CAR T-Cell biography: the use of military terms to describe its mode of action,

and an emphasis on 'cancer' or 'cancer cells' – terms which can carry significant emotional weight. CAR T-Cells are thus cast as an ally in a *biomedical-moral war against cancer*, and in some coverage, as a potential cure for cancer. Emotive titles include: "The Future of Cancer Treatment is Here, and it is Really Saving lives" (Plenke, 2016); and "Extraordinary Treatment Could be Cancer Breakthrough" (Jha, 2016).

Like the trachea, CAR T-Cells have also acquired a biography as a gateway technology. Academic literature highlights the potential for directing CAR T-Cells to a range of antigens, and corporate actors appear to have been influential in mobilising and taking advantage of this promissory identity dimension. In corporate representations, CAR T-Cells are framed as a *multivalent* technology platform which can be targeted towards various cancer types. This aspect appears to have provided momentum to commercial alliances that include big pharma which, in the past, has been reluctant to engage in the 'uncertain' field of RM. This is illustrated by the collaboration between Celectis, University College London, and Pfizer on the allogenic product UCART19, which was developed as an 'off-the-shelf' product by Cellectis and used in a high-profile compassionate use case involving a terminally-ill one year old girl with relapsed acute lymphoblastic leukaemia, who now appears to be cancer-free. The agreement means that Pfizer has the exclusive rights to develop and commercialise UCART directed at 15 specific cancer targets, while Celectis will develop and commercialise UCART directed at eight different cancer targets (Pfizer, 2014). Celectis and Pfizer, then, have been brought together by the perceived multivalency of UCART - which they anticipate will lead to multiple, legally-delineable and commercially lucrative markets. Indeed, it appears that the identity features of CAR T-Cells are providing significant affordances for big pharma.

4.4. Celution System (Cytori)

The Celution system is produced by Cytori, a US-based company focusing on cosmetic and reconstructive surgery. Celution is a closed, automated system for processing a patient's adipose tissue to obtain regenerative cells which can be used for several indications. Cell processing takes less than two hours, enabling it to be carried out at the 'point-of-care' during a surgical operation. The system corresponds to a 'bench-top' device: a centrifuge and electronic display are housed within a casing, which contains clips for a standardized, single-use disposable processing set. It is used in post-cancer breast reconstruction at several clinical sites in the UK, and in studies on treatments for fistula–in-ano, chronic wounds, chronic ischemic heart failure, and scleroderma (an autoimmune condition). Celution is regulated as a medical device within the EU. Generally the medical device regulatory pathway is considered less onerous than the EU's ATMP framework. Consequently, the system can be used without the need of a high-cost clinical-grade Good Manufacturing Practice facility. Similarly in the US, the extracted cells do not fall within the remit of the FDA's Cellular and Gene Therapy Pathway and such a facility is not required, though the regulatory pathway can be more onerous than that in the EU (Kramer et al., 2012): the device has conditional FDA approval for use within clinical trials. Influential actors in the development space of the Celution System include the manufacturer Cytori, regulators, and the clinical teams and institutions that are using and trialling the device.

Cytori and clinician-users are attempting to actively shape the biography of the system by emphasising its *plausibility* as a means of producing therapeutically useful regenerative material. These actors refer to this material as 'adipose-derived' regenerative cells, described as a heterogeneous cell population that includes:

> not just [adipose-derived stem cells], but also a substantial number of other cell types of therapeutic potential, including vascular endothelia cells, tissue macrophages and so forth (Fraser et al., 2014, 39).

Multiple mechanisms of therapeutic action are claimed, including "potential to improve outcome by replacing cells lost to injury, disease, and daily wear and tear" (Cytori, 2016). Hence, the system is represented as a means of obtaining and concentrating a *clinically useful* substance. A clinician interviewee who uses the device referred to it as 'turbo-charged' with regenerative material. In breast reconstruction, the interviewee added, this meant that the reconstruction procedure only required one graft, rather than – as in some cases – several. It thus provides an important opportunity for clinicians and their institutions to become involved in 'RM', without the need for an expensive manufacturing facility. Additionally, commercial and clinical actors emphasise the potentially wide range of indications that can be treated: wound care, autoimmune conditions, and heart failure. The system, then, has a biography in which it is presented as having a wide clinical scope.

Commercial and clinical-academic actors also emphasise the system's *organisational affordances* by framing it as producing regenerative cells in a standardized, automated fashion. It is thus positioned as being a relatively quick procedure "that can be used in a real time bedside manner" (Fraser et al., 2014, 38), or "at the point of care (in theatre, at the bed side, or within a hospital)" (Cytori, 2013). Here, its identity aligns with an envisaged ideal in RM: that current, labour-intensive and expensive open RM production systems will be replaced with closed automated systems. According to an interviewee, such organisational affordances had facilitated the adoption of the system within her hospital. Very little additional training is needed to use the device, nurses had been trained to use it, and it was possible to conduct other clinical work while the device was processing the regenerative material (Surgeon, Interview, written notes).

There is some tension relating to the cost of the device and the perceived cost effectiveness of the procedures in which it is used. One actor, the UK's NHS National Innovation Centre, conducted a cost-assessment of the System in breast reconstruction, concluding that it could lead to "significant cost savings for the NHS" (Winn, cited in Cytori, 2011). Yet, it has not been widely adopted within the NHS, probably because payers (hospitals and trusts) believe the initial cost to be too high. NICE has not recommended it. A clinician interviewee believed this was one reason why there had been reluctance within her institution to purchase the System. However, it was eventually purchased when clinicians working in other disease areas expressed a desire to use it (Surgeon, Interview, written notes). Its eventual adoption was thus influenced by its promissory identity of having several therapeutic applications.

Regulators are particularly influential actors within the development space of the Celution System. The implications of being classified as a medical device differ between the EU and the US, as indicated by marketing authorisation in the former but not the latter. In the US, its relative novelty and 'innovativeness' were at issue. If the device is considered significantly different from existing in-use devices ('predicate devices'), then it requires a PMA (premarket approval) with stringent data requirements, generally necessitating clinical trials. Cytori attempted to avoid this by framing their system as being sufficiently similar to existing devices that are used to draw and concentrate haematopoietic stem cells, thus constructing a biography of significant *homology with existing devices* and thus being of *limited novelty*. The FDA however disagreed, identifying the system as being *sufficiently novel* as to warrant a PMA. As a result, while the device is essentially 'on the EU

market' for certain indications, in the US it has acquired an identity as *investigational* with an *uncertain safety and efficacy profile*.

5. Discussion

The approach we have adopted here enables us to go beyond the usual policy discourse which presents innovation as being a process of identifying and overcoming technical and organisational challenges. We have used the notion of technology identities as an analytical frame for interrogating how expectations, identities and interests become entwined, and how innovation trajectories are forged as a result. We have focused on specific instances with a select though important group of technologies, and it is important to recognize the limitations of this narrow focus. However, in each of the case studies above, we see how technology identities are negotiated, maintained and in some cases contested by various actors within the development space, and hence how particular development pathways are collectively negotiated and enacted. We see that some technologies such as ACI acquire complex, contested identities which appear to limit their development and adoption, and we see that others, such as the trachea and the CAR T-Cells, acquire powerful promissory aspects that align diverse actors, providing momentum to further development and adoption. A summary of influential identity aspects is presented in Table 1.

The case studies indicate that within the field of RM, particular actors are more powerful than others in shaping influential technology identities and, consequently, development pathways. Pioneering clinicians, clinicians' academic and clinical institutions, and news media play an important role in framing and perpetuating technology identities, but unsurprisingly, regulatory agencies and HTA authorities are particularly powerful actors in shaping technology identities within the development spaces of RM. Identity aspects relating to regulatory classifications and comparative cost-effectiveness have major implications for the decision-making of other actors within the development space, and national differences between such agencies (and the different weightings placed on particular identity aspects) are reflected in the variation in development pathways across countries: the national commissioning of ChondroCelect in the Netherlands and not the UK is an example of this, as is the differing regulatory status of the Celution System in the UK and the US. Regulatory and HTA agencies are, then, powerful, authoritative actors in the problematisation (Callon, 1986) of emerging RM technologies: they delineate and define the technology, prompting other actors to orientate themselves accordingly. These problematisations may be perceived by other actors as creating barriers to further development and adoption of the technology, but they also present affordances; affordances that can lead to novel development trajectories for technologies endowed with particular identity aspects. For example, compassionate use of technologies classified as ATMPs is permitted by the EMA's ATMP framework (via 'exemptions/specials' schemes) which allows a clinician to prescribe them as a lifesaving measure on a one-off basis. In effect, this provides a development pathway for technologies with durable identities as being 'lifesaving'. This is illustrated by the bioengineered trachea case: as a 'plausible lifesaving' technology, it was permitted for in-

Table 1
Influential identity aspects of four RM technology case studies.

Technology/technique	Useful exemplar because …	Relational identity aspects, including summary (bold).	Powerful actors involved in *problematisation*.
Bioengineered trachea	Surgeon-led development: Project is heavily dependent on surgical skill; Has been used in patients via compassionate-use; Complex technology platform	*Lifesaving* technology Part of a *transplantation procedure* conducted at elite institutions; *Gateway technology* that leads to a future of immune-congruent, bespoke organ generation; *Pathfinding* technology for establishing a thriving RM industry in the UK **Among many actors, it has an influential but contested dual identity as lifesaving and as a promissory gateway to further innovation. Presents affordances for institutional actors.**	Regulators (European Medicines Agency, Medicines & Healthcare products Regulatory Agency); News media; Host clinical institutions
Autologous chondrocyte implantation (ACI): OsCell/MACI/ChondroCelect	MACI & ChondroCelect have received marketing authorisation; Have undergone formal health technology appraisals; Variable uptake in healthcare systems	A *regenerative medicine* technology; An *Innovative* technology; *Clinical useful*, but *not remarkable/exceptional* *Uncertain long-term effectiveness;* **Actors within the development space foreground different identity aspects, leading to a complex & contested identity that has led to variable uptake.**	Regulators (European Medicines Agency, Medicines & Healthcare products Regulatory Agency) Health Technology Assessment agencies (e.g. NICE)
CAR T-cells	A major area of activity within the field of RM; Represents high proportion of current clinical trials in RM; Represents a potential cure for some cancer types; An immunotherapy that entails gene-editing	*Easily delineable* and *monitorable;* *Lifesaving* technology; *Ally* in the biomedical-moral *war against cancer* - a potential *cancer cure* Potentially *multivalent*, *gateway technology;* **Among many actors, it has an influential dual identity as lifesaving and as a multivalent, gateway technology. Identity as 'multivalent' has facilitated innovation alliances.**	Regulators (European Medicines Agency, Medicines & Healthcare products Regulatory Agency) News media Corporate actors – big pharma
Celution 'Point of care' system	An automated close-system for cell processing; Classified as a medical device; Different regulatory statuses in the EU and the USA	*Plausible* means of producing regenerative material; Potentially wide *scope of applications;* Classification as a *medical device* producing non-ATMP regenerative material; *Organisational affordances/utility;* *Cost effective*, yet *too costly;* Sufficiently *novel* to require PMA (in USA); **Identity presents affordances for clinicians but not necessarily their institutions. Different regulatory frameworks have fostered a variable technology identity.**	Regulators, particularly European Medicines Agency, Food & Drug Administration

human compassionate use, enabling the generation of useful information to inform subsequent clinical trial protocols. The inhuman use generated media attention, and consolidated this identity, no doubt facilitating subsequent innovation alliances. Similarly, compassionate use of CAR T-Cell technology resulted in significant, highly optimistic media representations. We suggest, then, that compassionate use represents a significant development trajectory within the field of regenerative medicine.

It has been argued that the success of an innovation depends on its capacity to appeal to, and be co-opted by, the interests of a diverse range of actors (Brown and Webster, 2004). In the field of RM, we see that technology identity aspects such as 'lifesaving' resonate with the values and interests of actors (particularly gatekeeping actors), thus facilitating further development and potential adoption. In the case of CAR T-cells, this identity has been positioned within the culturally-resonant biomedical-moral war on cancer, providing it with additional symbolic potency. Another important identity aspect relates to the perceived scope of the technology. We showed that the Celution system has yet to be widely adopted, but its adoption in one clinic was justified by its multiple clinical and research applications. In particular, a dual identity as being both a current lifesaving technology, and a promissory gateway technology that will lead to further therapeutic and commercial opportunities, is a powerful dynamic aligning diverse actors, as illustrated by both the trachea and CAR-T Cells. The perceived multivalent potential of CAR T-Cells, for example, has led to new innovation alliances involving big pharma (Pfizer), smaller SMEs (Celectis) and research-intensive hospitals. Both the trachea and CAR T-Cell identities also have strategic utility for institutions: they represent affordances which enable a clinician's host institutions, for example, to present themselves via press releases as being at the forefront of RM. Additionally, we see that the trachea project has received support for a UK state-supported RM accelerator: it resonates with the CGTC's mandate to facilitate translation and commercialization. The establishment of the CGTC has, in effect, meant that an additional set of interests relating to industry building, wealth generation and national prosperity have become particularly influential elements of the development spaces within the field of RM.

We also see in the case studies that negotiations over appropriate development pathways can centre on the relative novelty of a technology. As much of the literature in the sociology of expectations has demonstrated (Borup et al., 2006; Brown and Michael, 2003), the delineation of a technology as 'novel' and 'innovative' can often provide momentum to its development or adoption by aligning actors - the decision of the Dutch authorities to fund ChondroCelect as an 'innovative new therapy' is an example. Studies have also illustrated that technologies with indistinct identities, or identities as being little different to other technologies (Ulucanlar et al., 2013), can limit their uptake. However, the cases studies presented here illustrate that actors may also strategically foreground such homologies. The trachea, for example, has acquired an identity as being part of a 'transplantation technique', relating it to the history of other transplantation procedures. Actors may contest the relative novelty/homology of the technology, resulting in the consolidation of a particular identity and corresponding pathway: The debate between Cytori and the FDA over the Celution System and its similarity with existing systems, and the resulting decision that a PMA would be required for the system, is an example of this.

Finally, we also see technology identities have been constructed that affirm national political imaginaries of 'health and wealth'. Both the bioengineered trachea and CAR T-Cell identities, for example, align with the commercialization innovation trajectory envisaged within UK Government's strategic 'Eight Great Technologies' policy (Willetts, 2013). However, as the ACI example illustrates, constructed identities can reflect tensions between such imaginaries and the State's role in governing access to new medicines. State-endorsed identity constructing mechanisms such as negative cost-effectiveness assessments can effectively bring dissemination to a halt.

References

Department for Business Innovation & Skills, 2011. Taking Stock of Regenerative Medicine in the United Kingdom. Department of Business, Innovation and Skills, London.

Adams, Stephen, 26 July 2012. Pioneering windpipe boy growing into healthy teenager (Accessed 19 February 2016). Telegraph. http://www.telegraph.co.uk/news/health/news/9426869/Pioneering-windpipe-boy-growing-into-healthy-teenager.html.

BASK, 2015. Appeal for Support for Autologous Chondrocyte Implantation. British Association for Surgery of the Knee, London.

Biant, L.C., McNicholas, M.J., Sprowson, A.P., Spalding, T., 2015. The surgical management of symptomatic articular cartilage defects of the knee: consensus statements from United Kingdom knee surgeons. Knee 22 (5), 446–449. http://dx.doi.org/10.1016/j.knee.2015.06.001.

Borup, Mads, Brown, Nik, Konrad, Kornelia, Lente, Harro Van, 2006. The sociology of expectations in science and technology. Technol. Analysis Strategic Manag. 18 (3–4), 285–298. http://dx.doi.org/10.1080/09537320600777002.

Brown, Nik, Michael, Mike, 2003. A sociology of expectations: retrospecting prospects and prospecting retrospects. Technol. Analysis Strategic Manag. 15 (1), 3–18. http://dx.doi.org/10.1080/0953732032000046024.

Brown, Nik, Webster, Andrew, 2004. New Medical Technologies and Society: Reordering Life. Polity, Cambridge.

Callon, Michel, 1986. Some elements of a sociology of translation: domestication of the scallops and the fishermen of st Brieuc Bay. In: Law, John (Ed.), Power, Action and Belief: a New Sociology of Knowledge? Routledge, London, pp. 196–223.

CGTC, 2014. The Cell Therapy Catapult: First Review to March 2014. Cell and Gene Therapy Catapult, London.

Cytori, 2011. NHS National Innovation Centre Identifies Celution(R) as Cost-effective Innovative Technology for Partial Breast Reconstruction. Cytori Therapeutics, Inc, San Diego CA.

Cytori, 2013. Public Consultation on the Regulation on Advanced Therapy Medicine Products. Cytori Therapeutics, San Diego CA.

Cytori, 2016. Science and Technology Overview (Accessed 29 February 2016). Cytori Therapeutics Inc. http://www.cytori.com/Technology/ScienceandTechnology.aspx.

Daily Mail Reporter, 2012. British Boy With First Windpipe Transplant is Thriving Two Years on - and Free from Medication. Mail Online, 26 July 2012(Accessed 19 February 2016). http://www.dailymail.co.uk/health/article-2179144/British-boy-windpipe-transplant-thriving-years-on.html.

Delaere, Pierre, 2010. Stem-cell "hype" in tracheal transplantation. Transplantation 90 (8), 927–928. http://dx.doi.org/10.1097/TP.0b013e3181f10f18.

Delaere, Pierre R., Van Raemdonck, Dirk, 2014. The trachea: the first tissue-engineered organ. J. Thorac. Cardiovasc. Surg. 147 (4), 1128–1132. http://dx.doi.org/10.1016/j.jtcvs.2013.12.024.

DeLanda, M., 2006. A New Philosophy of Society. Assemblage Theory and Social Complexity: Bloomsbury Academic.

EMA, 2014. EPAR Summary for the Public: ChondroCelect. European Medicines Agency, London.

Fraser, John K., Hicok, Kevin C., Shanahan, Rob, Zhu, Min, Miller, Scott, Arm, Douglas M., 2014. The Celution® system: automated processing of adipose-derived regenerative cells in a functionally closed system. Adv. Wound Care 3 (1), 38–45. http://dx.doi.org/10.1089/wound.2012.0408.

Gardner, John, Faulkner, Alex, Mahalatchimy, Aurélie, Webster, Andrew, 2015. Are there specific translational challenges in regenerative medicine? Lessons from other fields. Regen. Med. 10 (7), 885–895. http://dx.doi.org/10.2217/rme.15.50.

Gardner, John, Webster, Andrew, 2016. The social management of biomedical novelty: facilitating translation in regenerative medicine. Soc. Sci. Med. 156, 90–97. http://dx.doi.org/10.1016/j.socscimed.2016.03.025.

House of Lords Science and Technology Committee, 2013. Regenerative Medicine Report. House of Lords, London.

Jha, Alok, 2016. Extraordinary Treatment Could Be Cancer Breakthrough, 16 February 2016(Accessed 22 February 2016). ITV. http://www.itv.com/news/2016-02-16/extraordinary-treatment-could-be-cancer-breakthrough/.

Keating, P., Cambrosio, A., 2003. Biomedical Platforms: Realigning the Normal and the Pathological in Late-twentieth-century Medicine. MIT Press, Cambridge MA.

Kramer, Daniel B., Xu, Shuai, Kesselheim, Aaron S., 2012. Regulation of medical devices in the United States and european union. N. Engl. J. Med. 366 (9), 848–855. http://dx.doi.org/10.1056/NEJMhle1113918.

Latour, Bruno, 2005. Reassembling the Social: an Introduction to Actor-network Theory. Oxford University Press, Oxford.

Latour, B., Woolgar, S., 1986. Laboratory Life: the Construction of Scientific Facts. Princeton University Press, Princeton NJ.

Law, John, 2008. Actor-network theory and material semiotics. In: Turner, Bryan

(Ed.), The New Blackwell Companion to Social Theory. Blackwell, Oxford, pp. 141–158.
MacRae, Fiona, 2015. Our Little Miracle! Baby Girl Battling Leukaemia Saved by 'Revolutionary' Cell Treatment. Mail Online, 5 November 2015(Accessed 23 February 2016). http://www.dailymail.co.uk/health/article-3305603/World-baby-girl-battling-leukaemia-saved-miracle-treatment-Genetically-modified-cells-hunt-kill-disease-transform-cancer-care.html.
Mahalatchimy, A., Rial-Sebbag, E., Tournay, V., Faulkner, A., 2012. The legal landscape for advanced therapies: material and institutional implementation of European Union rules in France and the United Kingdom. J. Law Soc. 39 (1), 131–149.
McCaskie, A.W., 2015. From needle to knife. Bone Jt. J. 97-B (1), 1–2. http://dx.doi.org/10.1302/0301-620x.97b1.34963.
Mol, A., 2002. The Body Multiple: Ontology in Medical Practice. Duke University Press.
Morrison, Michael, 2012. Promissory futures and possible pasts: the dynamics of contemporary expectations in regenerative medicine. BioSocieties 7 (1), 3–22.
Globe Newswire, 2016. TiGenix Reconfirms Strategic Focus on its Allogeneic Stem Cell Platforms.
NICE, 2015. Appraisal Consultation Document: Autologous Chondrocyte Implantation for Repairing Symptomatic Articular Cartilage Defects of the Knee (Including a Review of TA89). National Institute for Health and Care Excellence, London.
Oerlemans, A.J., van Hoek, M.E., van Leeuwen, E., Dekkers, W.J., 2014. Hype and expectations in tissue engineering. Regen. Med. 9 (1), 113–122. http://dx.doi.org/10.2217/rme.13.89.
Omidvar, Omid, De Grijs, Myriam, Castle, David, Mittra, James, Rosiello, Alessandro, Tait, Joyce, 2014. Regenerative Medicine: Business Models, Venture Capital and the Funding Gap. Innogen, Edinburgh.
Peirce, Susan C., Faulkner, Alex, Ulucanlar, Selda, Elwyn, Glyn, 2015. Technology identities explain under- and non-adoption of community-based point-of-care tests in the UK NHS. Health Policy Technol. 4 (1), 68–77. http://dx.doi.org/10.1016/j.hlpt.2014.10.014.
Pfizer, 2014. Pfizer and Cellectis Enter into Global Strategic Cancer Immunotherapy Collaboration. Pfizer Inc.
Pinch, Trevor J., Bijker, Wiebe E., 1984. The social construction of facts and artefacts: or how the sociology of science and the sociology of technology might benefit each other. Soc. Stud. Sci. 14 (3), 399–441. http://dx.doi.org/10.1177/030631284014003004.
Plenke, M., 19th Feb 2016. The future of cancer treatment is here, and It's really saving lives, 18 February 2016(Accessed 22 February 2016). Yahoo News. http://news.yahoo.com/future-cancer-treatment-really-saving-200400178.html.
Pollock, Neil, Williams, Robin, 2010. The business of expectations: how promissory organizations shape technology and innovation. Soc. Stud. Sci. 40 (4), 525–548. http://dx.doi.org/10.1177/0306312710362275.
Regenerative Medicine Expert Group, 2015. Building on Our Own Potential: a UK Pathway for Regenerative Medicine (London).
Roberts, Michelle, 19 November 2008. Windpipe transplant breakthrough, 19 November 2008(Accessed 19 February 2008). BBC News. http://news.bbc.co.uk/1/hi/health/7735696.stm.
Schneider, Leonid, 2016. Macchiarini, Birchall, Seifalian and EU-funded Human Experimenting (Accessed 10 August 2016). wordpress. https://forbetterscience.wordpress.com/2016/03/27/macchiarini-birchall-seifalian-and-eu-funded-human-experimenting/.
Tomlin, Zelda, Peirce, Susan, Elwyn, Glyn, Faulkner, Alex, 2013. The Adoption Space of Early-emerging Technologies: Evaluation, Innovation, Gatekeeping (PATH). Final report. NIHR Service Delivery and Organisation programme.
UK Research Councils, 2012. A Strategy for UK Regenerative Medicine. Medical Research Council, London.
Ulucanlar, S., Faulkner, A., Peirce, S., Elwyn, G., 2013. Technology identity: the role of sociotechnical representations in the adoption of medical devices. Soc. Sci. Med. 98, 95–105 doi. http://dx.doi.org/10.1016/j.socscimed.2013.09.008.
Vertes, 2016. Lessons for Accelerating the Stem Cell and Regenerative Medicine Industr. RegMedNet. RegMedNet Website: RegMedNet.
Willetts, David, 2013. Eight Great Technologies. Department of Business, Innovation and Skills, London.
Yuhas, Alan, 15 Feb 2016. Cancer researchers claim 'extraordinary results' using T-cell therapy, 15 February 2016(Accessed 23 February 2008). Guard. https://www.theguardian.com/science/2016/feb/15/cancer-extraordinary-results-t-cell-therapy-research-clinical-trials.