The costs and consequences of assisted reproductive technology: an economic perspective

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Submitted on February 1, 2010; resubmitted on April 20, 2010; accepted on April 26, 2010

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BACKGROUND: Despite the growing use of assisted reproductive technologies (ART) worldwide, there is only a limited understanding of the economics of ART to inform policy about effective, safe and equitable financing of ART treatment.

METHODS: A review was undertaken of key studies regarding the costs and consequences of ART treatment, specifically examining the direct and indirect costs of treatment, economic drivers of utilization and clinical practice and broader economic consequences of ART-conceived children.

RESULTS: The direct costs of ART treatment vary substantially between countries, with the USA standing out as the most expensive. The direct costs generally reflect the costliness of the underlying healthcare system. If unsubsidized, direct costs represent a significant economic burden to patients. The level of affordability of ART treatment is an important driver of utilization, treatment choices, embryo transfer practices and ultimately multiple birth rates. The costs associated with caring for multiple-birth ART infants and their mothers are substantial, reflecting the underlying morbidity associated with such pregnancies. Investment analysis of ART treatment and ART-conceived children indicates that appropriate funding of ART services appears to represent sound fiscal policy.

CONCLUSIONS: The complex interaction between the cost of ART treatment and how treatments are subsidized in different healthcare settings and for different patient groups has far-reaching consequences for ART utilization, clinical practice and infant outcomes. A greater understanding of the economics of ART is needed to inform policy decisions and to ensure the best possible outcomes from ART treatment.

Key words: assisted reproductive technologies / in vitro fertilization / multiple births / costs / health economics
Background

Since the birth of Louise Brown, the world’s first IVF baby some 30 years ago, the use of assisted reproductive technologies (ART), such as IVF, have transformed the treatment of infertility and subfertility. These technologies, which by definition involve the handling of human gametes or embryos (ICMART, 2009a), elicit a significant medical, reproductive and economic influence in developed countries. It is estimated that 3.5 million children have been born worldwide following ART treatment (ESHRE, 2008), with ART children making up to 4% of births in some European countries (ESHRE, 2009a). The number of cycles performed in many developed countries has grown by 5–10% per annum over the last 5 years (ESHRE, 2004; CDC and ASRM/SART, 2008; ESHRE, 2009a; Wang et al., 2009). The combined estimate from the USA, European, Australian and New Zealand ART registries alone indicates that over 600 000 ART cycles were undertaken in 2005 resulting in the birth of over 120 000 infants (CDC and ASRM/SART, 2007; Wang et al., 2007; ESHRE, 2009a).

The picture is less clear at a global level, and in particular in less developed countries, which undertake a fraction of the ART cycles performed in developed countries despite having a similar subfertility prevalence (World Health Organization, 2003; Nachtigall, 2006). However, the latest survey undertaken by the International Committee for Monitoring Assisted Reproductive Technology (ICMART) estimates that approximately 1 million ART cycles were undertaken worldwide in 2002, an increase of 12% compared with the year 2000 (ICMART, 2009a). The increasing use of ART likely reflects the trend of later childbearing and its associated impact on age-related fecundity, rising rates of obesity and some sexually transmitted diseases, as well as increasing awareness, success and acceptance of reproductive technologies (Adashi et al., 2000; Kovacs et al., 2003; Jensen et al., 2008).

Despite the growing use of ART, there is limited understanding of the economics of ART to guide clinical practice and to inform policy (Collins, 2002; Garceau et al., 2002). There are a number of features that distinguish ART from other healthcare interventions and that pose unique challenges for health economists and policy-makers. Such differences mainly arise from the difficulty in comparing fertility treatment to other uses of healthcare resources, with fertility treatments generating new life, while most other medical interventions are judged by their ability to save, extend or improve the quality of life. Furthermore, fertility treatment has considerable ethical, moral and religious associations, which cannot be easily measured or valued by economic methods. However, an understanding of the economics of ART is particularly important because it continues to represent a growth market with wide applicability. Furthermore, the financing of ART has far-reaching implications on access and uptake of fertility treatment and ultimately on the health of infants born from these technologies (Collins, 2002; Reynolds et al., 2003; Chambers et al., 2009; Connolly et al., 2009a).

The work discussed in this paper was performed on behalf of the European Society of Human Reproduction and Embryology (ESHRE) Infertility and Society Task Force. The purpose of this paper is to provide an overview of the economic costs and consequences of ART, focusing on utilization, direct and indirect costs of treatment, the relationship between subsidization, affordability and clinical practice and the broader economic consequences of ART-conceived children. This review does not address cost-effectiveness analyses among ART and different fertility treatments and between alternate ART strategies, nor have the non-economic costs and consequences of ART treatment been discussed.

Methods

Multiple strategies were used to identify relevant epidemiological and economic studies. English language publications were searched in MEDLINE, EMBASE, ECONLIT and the Cochrane Library using the following key words: in vitro fertilization, IVF, assisted reproductive technology, infertility, health economics, cost, cost analysis, cost-effectiveness, cost–benefit analysis and utilization. ART registry reports were sourced from the USA, Europe and Australia and New Zealand. Bibliographies were cross-referenced to identify additional relevant studies. The importance and relevance of articles and reports were established after reviewing abstracts and report summaries. Where applicable, costs were indexed to 2006 using medical consumer price indices, and converted to euros using average 2006 interbank exchange rates.

ART utilization

The inability to conceive a planned child is the source of significant personal suffering to millions of couples around the globe. ‘Infertility’, a term typically referring to the failure to achieve a clinical pregnancy after 12 months or more of regular unprotected sexual intercourse (ICMART, 2009a), affects approximately 9% of couples at any given time worldwide (Boivin et al., 2007). While most pregnancies occur within 6 months of appropriately timed intercourse, a considerable proportion of couples who do not achieve pregnancy in the first 12 months go on to conceive spontaneously during the following year (Snick et al., 1997; te Velde et al., 2000; Gnoth et al., 2005; van der Steeg et al., 2007). Hence, human fertility is a continuous rather than a dichotomous phenomenon, which is reflected by the recent trend in the medical literature to refer to couples seeking fertility treatment as ‘subfertile’ rather than ‘infertile’ or ‘sterile’. A number of surveys suggest that approximately half of all subfertile couples in developed countries will seek healthcare assistance, with this proportion increasing in more recent surveys (Boivin et al., 2007; Moreau et al., 2008).

Despite a substantial increase in the number of ART cycles performed worldwide during the past decade, there are considerable international differences in the availability of ART treatments and per capita utilization rates (Collins, 2002). A recent review of economic aspects of ART in developed countries, for example showed that while the USA performed the largest number of ART cycles, it had one of the lowest utilization rates of developed countries with 373 non-donor cycles per year per million of the population. By comparison, Australia and Scandinavia had relatively high utilization rates of 1574 and 1465 non-donor cycles per year per million of the population, respectively (Chambers et al., 2009). Given that approximately one-half of couples do not seek medical assistance for subfertility, there is potentially a high unmet demand for ART treatment. ESHRE estimates that 1500 couples per million of the population requires ART treatment annually (ESHRE, 2001). Although couples may undergo more than one cycle in a given year, 1500 cycles per annum is considered a conservative underestimate (Collins, 2002;
Collins and Van Steirteghem, 2004; Ontario MHLTC, 2006). Therefore, while Australia and Scandinavian countries achieved this benchmark, only 25 and 40% of the demand for ART treatment cycles was met in North America and the UK, respectively (Chambers et al., 2009).

ART utilization rates are contingent on a number of inter-related factors that are not completely understood. The impact of some of these factors are obvious such as the restrictiveness of the legislative framework and the availability of treatment among countries, but other factors are less obvious, such as the affordability of treatment from a consumer and national perspective, the underlying political and healthcare system, together with socio-cultural, socio-economic and religious forces (Hughes and Giacomini, 2001; Collins, 2002; Nachtigall, 2006; Chambers et al., 2009).

**Direct costs**

Costs associated with ART treatment can be characterized as ‘direct’ costs; attributed to providing ART treatment itself, and ‘indirect’ costs; those occurring as a consequence of ART treatment. Direct cost include medical consultations, ovulation stimulation drugs, laboratory and embryology services, ultrasound scanning, medical procedures such as oocyte retrieval and embryo transfer, hospital charges, nursing and counselling services and administrative and overhead charges. Although different studies have used different definitions, these costs are relatively easily identifiable and quantifiable.

The results summarized in Fig. 1 provide an overview of estimates of the direct costs of ART treatment cycles over the last decade in selected countries. It shows that direct ART treatment costs show considerable variation among countries, with the USA standing out as the most expensive and Northern European countries and Japan being less expensive. The costliness of treatment tends to reflect the costliness of the underlying healthcare system. The USA is the most costly healthcare system in the world in terms of both the percentage of gross domestic product (GDP) spent on healthcare and the per capita spending on healthcare, spending almost 2.0 and 2.5 times per capita on healthcare than does the Netherlands and Japan, respectively (OECD, on line database).

In addition to the cost of an individual treatment cycle, the economic impact of ART is also related to the volume of treatments undertaken in a country, and how much of the total healthcare dollar this consumes. In the recent review of developed countries by Chambers and colleagues, ART treatment amounted to 0.25% or less of total healthcare expenditure in all countries surveyed, with ART treatment comprising more of the health dollar in countries offering public funding, such as Australia and Scandinavian countries, to as little as 0.06% in the USA, which has no public funding (Chambers et al., 2009). By comparison, conservative estimates from cost-of-illness studies indicate that obesity accounts for almost 10 and 2–4% of total healthcare spending in the USA and Europe, respectively (Branca et al., 2007; Finkelstein et al., 2009). Therefore, while ART treatment may be expensive from an individual’s perspective it is not from a national healthcare perspective. This finding is also supported by a number of costing analyses of ART as part of medical insurance plans (Collins et al., 1995; Griffin and Panak, 1998; Hiddlebaugh et al., 1997).

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**Figure 1** Estimates of the direct cost of one fresh ART treatment cycle (euro 2006). (1) Henne et al., 2008; (2) Chambers et al., 2009; (3) Chambers et al., 2009; (4) Chambers et al., 2009; (5) Chambers et al., 2009; (6) Strandell et al., 2005; (7) NICE, 2004; (8) Maheshwari et al., 2009; (9) Koivurova et al., 2004; (10) Chambers et al., 2009; (11) Thun Kjellberg et al., 2006; (12) de Mouzon et al., 2004; (13) Bouwmans et al., 2008 and (14) De Sutter et al., 2002. Note: costs are indexed to 2006 using medical consumer price indexes, and converted to euros using average 2006 interbank exchange rates.
Cost-effectiveness ratios for ART treatment are generally expressed as the average direct costs of treatment per live birth (with twins and triplet counted as one live birth). This ratio is calculated as the total ART treatment costs divided by the number of live birth deliveries; therefore, reflecting both the costliness and efficacy of treatment. Because of the high treatment costs in the USA cost-effectiveness ratios are relatively high (~€35,000 per live birth) compared with countries such as Japan with less expensive treatment (~€20,000 per live birth) (Collins, 2002; Chambers et al., 2009). Furthermore, because of the age-related decline in ART success rates, the average cost per live birth for non-donor cycles increases significantly with female age (Legro et al., 1997; Suchartwatnachai et al., 2000; NICE, 2004; Chambers et al., 2006; Sullivan et al., 2008). Estimates from the National Institute for Clinical Excellence (NICE) indicate that the costs per live birth are similar for ages 24 (€17,000) and 33 (€18,500), after which they begin to increase, with the cost per live birth reaching €54,000 at age 42 (NICE, 2004). On average ART was performed on women older than 35 years of age in almost half of all reported treatments worldwide in 2002, and on women 40 years and older in just over 14% of treatments. However, there are important differences in the age distribution of women undergoing treatment among countries, with the proportion of women 40 years of age and older considerably higher in Australia, Asia and North America than in the Middle East and Europe (ICMART, 2009b).

## Indirect Costs

One of the most significant challenges facing ART treatments is the high incidence of multiple birth pregnancies. The latest published figures indicate that multiple births still account for 31, 22, 10% of all deliveries after such procedures in the USA, Europe and Australia, respectively (CDC and ASRM/SART, 2008; ESHRE, 2009a; Wang et al., 2009). While the poorer clinical outcomes of multiple birth pregnancies are well described, e.g. (Elster, 2000; ESHRE, 2003; Helmerhorst et al., 2004; Fauser et al., 2005), the indirect costs associated with caring for ART multiple birth infants and their mothers are less appreciated. However, it has been estimated that the cost of care of ART multiples can exceed the cost of ART treatment itself (Collins and Graves, 2000). Table I provides an overview of recent estimates of the perinatal healthcare costs associated with caring for ART singleton and multiple birth infants and mothers. While the methods used to quantify the costs vary among studies, the economic burden placed on healthcare systems to care for ART twins and triplets is substantially greater than if the infants had been born as singletons. In addition, the costs of caring for multiple birth infants have been shown to extend well beyond the perinatal period, reflecting the on-going morbidity associated with a significant proportion of multiple birth infants (Petrou, 2005; Stevenson et al., 1996a; Stevenson et al., 1996b; Koivurova et al., 2007).

An estimate of the combined direct and indirect costs of ART treatment in Finland found that the cost (inflated to 2006) of an ART singleton and twin birth per woman was €24,377 and €35,042 up to 27 days after birth (Koivurova et al., 2004).

To limit the incidence of multiple birth pregnancies, most ART clinical guidelines now recommend limiting the number of multiple embryo transfers in favour of single embryo transfer in most patient groups (HFEA, 2003; ASRM, 2006; RTAC, 2005). Furthermore, the importance of the indirect costs of ART is increasingly recognized in the structuring of public financing and regulation of ART treatment in countries such as Belgium, Sweden and New Zealand. In Belgium, for example, only one embryo can be transferred in the first two cycles in women aged <36 years, and two embryos in the third to sixth cycle. In women aged ≥36 years, two or three embryos may be transferred. Reports suggest that this has led to a reduction in multiple birth rates to less than 10% without substantially affecting the overall pregnancy rate (Gords et al., 2005; MBSG, 2006; Karlstrom and Bergh, 2007). Such initiatives are supported by a number of studies that have demonstrated that a policy of elective single embryo transfer in women at risk of twinning, augmented by effective cryopreservation programs, is both clinically and cost-effective (Wolner-Hanssen and Rydstrom, 1998; De Sutter et al., 2002; Gerras et al., 2002; Tiitinen et al., 2003; Gerras et al., 2004; Thurin et al., 2004; Thurin Kjellberg et al., 2006; Heijnen et al., 2007).

In addition to the risks associated with ART multiple births, recent studies have shown that ART singleton pregnancies also have an increased risk of poorer perinatal and long-term health outcomes compared with spontaneously conceived singleton pregnancies (Dhont et al., 1999; Jackson et al., 2004; Schieve et al., 2004a, b; Basatemur and Sutcliffe, 2008). Two studies have shown that these poorer outcomes are significant enough to be reflected in the higher healthcare costs of caring for ART singletons compared with naturally conceived singletons (Koivurova et al., 2004; Chambers et al., 2007; Koivurova et al., 2007). Whether these poorer outcomes are due to differences between couples seeking fertility treatment and those who spontaneously conceive, or fertility treatment per se has not been fully elucidated. A number of studies have shown that subfertility is associated

<table>
<thead>
<tr>
<th>Country (year)</th>
<th>Singleton deliveries</th>
<th>Twin deliveries</th>
<th>Triplet deliveries</th>
<th>Time period</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (2002)</td>
<td>€5410</td>
<td>€14 897</td>
<td>€52 836</td>
<td>Pregnancy to 1 year after birth</td>
<td>Ledger et al., 2006</td>
</tr>
<tr>
<td>The Netherlands (2002)</td>
<td>€2625</td>
<td>€13 873</td>
<td>NA</td>
<td>Pregnancy to 6 weeks after birth</td>
<td>Lukassen et al., 2004</td>
</tr>
<tr>
<td>Finland (2001)</td>
<td>€6240</td>
<td>€16 826</td>
<td>NA</td>
<td>Pregnancy to 27 days after birth</td>
<td>Koivurova et al., 2004</td>
</tr>
<tr>
<td>Australia (2003/04)</td>
<td>€5285</td>
<td>€15 237</td>
<td>€59 561</td>
<td>Inpatient birth admission to first discharge</td>
<td>Chambers et al., 2007</td>
</tr>
</tbody>
</table>

Note: Costs are indexed to 2006 using medical consumer price indexes, and converted to euros using average 2006 interbank exchange rates.

NA, not available.
with less favourable infant outcomes, including an increased risk of perinatal death, than in fertile couples (Draper et al., 1999; Basso and Baird, 2003; Ombelet et al., 2006). In addition, the spontaneous reduction of ART twin pregnancies to viable singleton pregnancies in up to 20% of ART twin gestation pregnancies (Kovacs et al., 2004) does not reduce the risk of the surviving singleton to the risk level of a pregnancy that originated as a singleton (Dickey et al., 2002; Pinborg et al., 2005; Chasen et al., 2006; Shebl et al., 2008).

**Subsidization and affordability**

The funding and regulatory framework for the provision of ART treatment varies considerably around the world and tends to be in line with the level of public and private responsibility for purchasing healthcare. Public financing of ART ranges from virtually no subsidization in the USA and most developing countries to funding of a limited number of cycles based on female age in most European countries; to unrestricted reimbursement with co-payments in Australia (Hughes and Giacomini, 2001; Nachttgall, 2006; Chambers et al., 2009). The most recent International Federation of Fertility Societies (IFFS) survey showed that roughly 50% of countries had no reimbursement through national health services or private insurers in 2004 (IFFS, 2007); however, there was a higher proportion of countries with some level of subsidization than in the previous survey undertaken in 2002 (IFFS, 2004).

Historically, justification for limiting reimbursement by funding authorities related to the view that infertility was a socially constructed need rather than a medical disorder, or that ART fell into the realm of experimental treatment (Redmayne and Klein, 1993; Neumann, 1997; Adashi et al., 2000; Gloucestershire NHS, 2006).

Increasingly it is recognized that the ability to pay for treatment, so-called ‘financial access’ plays a critical role in overall access to fertility treatment, as well as the choice of fertility treatment. An analysis of the National Survey of Family Growth in the USA found that neither infertility treatment, as well as the choice of fertility treatment. An analysis of the National Survey of Family Growth in the USA found that neither infertility nor insurance influenced the probability of seeking advice for infertility, a relatively inexpensive service, but that the choice to pursue expensive treatments, such as ART, was highly influenced by income (Staniec and Webb, 2007).

It is not just the cost of ART treatment that is important in terms of access to care, but also how affordable treatment is. Affordability is a measure of the economic burden placed on couples to fund their own treatment, therefore an ART treatment cycle may be very costly, but if it is highly subsidized it may become highly affordable for many patients. The few studies available on financial access to care suggest that affordability is a powerful determinant of whether couples will pursue treatment (Collins, 2002; Chambers et al., 2009; Connolly et al., 2009). The recent economic review of economic aspects of ART in developed countries found that the cost of a single fresh ART cycle as a percentage of an individual’s annual disposable income ranged from 50% in the USA, and approximately 20% in the UK, Scandinavian countries and Australia, to 12% in Japan. After accounting for government subsidies, the resultant cost to the patient of an ART cycle was unchanged in the USA and Japan (due to negligible public funding for ART treatment) but fell to approximately 12% of annual disposable income in the UK and Scandinavian countries. As expected, the greatest effect of subsidization was in Australia with a 71% reduction in the cost of an ART cycle as a percentage of disposable income, from 19% before government subsidization to 6% after government subsidization (Chambers et al., 2009) (Fig. 2).

Such differences in the affordability of treatment would predict differences in the level of utilization, and while there is a trend to high per capita utilization in countries with more affordable treatment (e.g. Australia has one of the highest utilization rates of ART in the world, while the USA has one of the lowest), the picture cannot be fully explained by affordability alone. A number of studies comparing ART utilization across different states in the USA with and without insurance coverage for fertility treatment show that even when the cost of treatment is subsidized, ART treatment tends to be more frequently used by older, wealthier, more highly educated Caucasian women. Furthermore, racial, ethnic and educational disparities in access to fertility care are not generally reduced by state insurance mandates to cover fertility treatment (Bitler and Schmidt, 2006; Jain, 2006; Hammoud et al., 2009).

A detailed study of ART in three countries undertaken by the RAND Corporation (Hoorens et al., 2008) concluded that restricted treatment and limited financial access encourages patients to seek cross-border reproductive care in countries with cheaper or less restrictive treatment than those in their native country. A recent survey of the reasons patients sought cross-border reproductive care in six European countries was unable to fully quantify the impact of cost, but found that only 13% of patients received partial reimbursement and 4% received total reimbursement in their native country (Shenfield et al., 2010). A risk of cross-border care is that it can lead to different standards of care and less responsible embryo transfer practices (Pennings et al., 2008). Furthermore, when such

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**Figure 2** Average cost of a standard IVF cycle as a percentage of annual disposable income in selected developed countries in 2006. Notes: 1. Reproduced from Chambers et al., 2009 with permission from Elsevier Publishing. 2. Annual disposable income is based on a single person at 100% of average earnings with no dependents. 3. The estimated percentage reduction in the average price of a standard IVF cycle due to government subsidization was 11% for Canada, 25% for the UK, 50% for Scandinavia, 0% for Japan and 71% for Australia. 4. In the USA, there is negligible government subsidisation for ART, however, the central role of private insurance in the USA was included in the analysis, reducing the average price of a standard cycle by 12%.
treatment is successful, the maternal, perinatal and lifetime healthcare costs are borne by the native healthcare system. There is also some anecdotal evidence that a lack of affordable treatment incentivizes patients and clinicians to opt for cheaper fertility treatments, such as stimulated intruterine insemination and ovulation stimulation, which have less controllable means of minimizing multiple births. Such treatments are not as highly monitored by national registries and can often be undertaken by non-specialist practitioners (Fauser et al., 2005; Ombelet et al., 2006; ESHRE, 2009a,b).

Demand for healthcare, including ART treatment, responds to changes in the consumer price, with demand for specific classes of healthcare being more or less sensitive to price. The measure of the responsiveness of demand to changes in consumer price is known as the price elasticity of demand and is often used by policy-makers to determine the impact of policy changes that will affect consumer payments. A recent study conducted in Germany suggests that a 10% price increase in ART treatment, associated with the introduction a co-payment for ART, likely reduced utilization by 4.1% for IVF and 3.4% for intracytoplasmic sperm injection (Connolly, 2009a). This suggests that when treatment access is dependent on user fees, costs are preventative for many patients. Moreover, an analysis of user fees among selected developed countries suggests that the price elasticity of demand for ART varies by price, with consumer prices in the mid-range (€2400–4800 per cycle) showing greater price elasticity than those at the extremes (Chambers et al., 2009).

The relationship between the costs faced by consumers and patient dropout has been explored in a variety of studies. Because fertility treatment costs are high it is tempting to suggest that this might be one of the main reasons for discontinuing treatment once it has been initiated. While cost is often one of the most prominent variables explaining discontinuation rates, psychological and physical factors have been found to be more influential in decision-making on whether or not to continue ART treatment (Goldfarb et al., 1996; Malcolm and Cumming, 2004; Rajkhowa et al., 2006). This would suggest that cost more likely influences whether couples decide to access treatment at all. This is supported by price-elasticity studies in other healthcare areas where costs often influence decisions to pursue treatment rather than the volume of consumption once the initial decision to be treated has been made (Ringel et al., 2005). This might suggest that people who can afford access to ART to begin with are more likely to discontinue for reasons other than cost.

Clinical practice and affordability

Treatment affordability has also been shown to influence clinical practice and treatment choices made by consumers and providers. Analysis of USA data suggests that embryo transfer practices are impacted by the presence of state-mandated insurance coverage, with states requiring full insurance coverage transferring lower average numbers of embryos per cycle than states with partial or no insurance coverage. States with state-mandated insurance coverage also have lower live birth rates per cycle and lower multiple birth rates (Jain et al., 2002; Reynolds et al., 2003; Henne and Bundorf, 2008). Similar differences in embryo transfer practices have also been observed between the USA, which is characterized by high treatment costs and low affordability and Europe, which typically has less costly treatment and more generous funding arrangements (Gleich et al., 2006). The predominant hypothesis proposed to explain these differences is that the substantial economic burden placed on individuals in markets without subsidization (through either public or private insurance) creates a strong financial incentive to achieve pregnancy in a limited number of cycles, theoretically leading to the transfer of multiple embryos. However, whether differences in live birth rates and multiple birth rates are solely due to differences in embryos transfer practices, or are also partly due to differences in patient characteristics, remains unclear (Reynolds et al., 2003; Henne and Bundorf, 2008). There is some evidence for example, that a greater proportion of patients with a poorer prognosis access ART treatment when it is subsidized due to lower expected benefits from treatment. These patients have fewer embryos to transfer and lower implantation rates, which in turn results in lower multiple birth rates (Reynolds et al., 2003). Conversely, a greater proportion of patients with a good prognosis may also access ART when it is subsidized, rather than continue to attempt a spontaneous conception. In this group of patients it would also be typical to transfer lower numbers of embryos resulting in lower multiple births. A recent examination of the relationship between competition among USA ART clinics and ART treatment outcomes found no evidence that the level of competition was associated with the number of embryos transferred, but that clinics in competitive markets treat a relatively lower proportion of younger women (Henne and Bundorf, 2010).

Broader economic consequences of ART-conceived children

A limited number of studies have attempted to value ART-conceived children in economic terms. While fertility treatment leads to the creation of human life, the desired outcome for infertile couples, few studies have quantified the broader economic impact these children represent to society. With the number and proportion of children born from fertility treatment increasing each year, there is a need to better understand the wider societal impact of these treatments in both developed and developing countries. A potential externality of fertility treatment concerns the long-term fiscal effect that ART children have on government accounts over many generations. Throughout their lifetime, these children will engage in economic activities that influence financial transfers between the state and citizen in the form of healthcare, education and future tax payments. A modelling approach referred to as generational accounting was developed in the 1990s to assess the economic consequences of individuals both in terms of future taxes as well as demand for government resources and the sustainability of fiscal policy decisions over generations (Kotlikoff, 1992). Such long-term fiscal policy analysis is not new; it has for example been used to estimate the economic and fiscal benefits of immigration in the USA (Smith and Edmonston, 1997; Auerbach and Oreopoulos, 1999a). In recent years, the approach has gained importance because of fiscal concerns arising from ageing populations and is used by numerous government ministries, the European Commission and the World Bank (Auerbach et al., 1999b; European Commission, 2000).

Three recently reported microeconomic studies have sought to address the long-term fiscal implications of an ART-conceived child.
from a government perspective in Sweden (Svensson et al., 2008), the USA (Connolly et al., 2008) and the UK (Connolly et al., 2009b) by applying a generational accounting framework to evaluate ART funding policies (Kotlikoff, 1992). The analytical framework explicitly recognizes that ART-conceived children have fiscal implications for government over many generations both in terms of future government spending and tax revenue with the difference defined as net tax revenue. Findings from the UK, which are also reflected in the Swedish and USA studies, indicate that the discounted net tax revenue paid over the lifetime of a singleton IVF child born in 2005 to the state are roughly £110 000. This is considerable compared with the treatment costs of approximately £13 000 to achieve an IVF-conceived child, representing an approximate 8-fold return on investment for government. The generational accounting framework applied to ART-conceived children is also useful for highlighting the long timeframes that are required to evaluate economic costs and benefits of fertility programs.

Attaching future tax revenue to ART-conceived children may be a compelling argument to increase funding. However, caution is necessary in applying these results in a policy framework that needs to be considered in the broader context of other government policies and initiatives that influence government accounts. Furthermore, if raising tax revenue is an explicit goal of government, then ART funding would need to be compared with other government initiatives and their impact on government tax revenues.

The generational accounting tax approach applied to ART-conceived children raises questions about the relationship between population growth and economic growth. In reality, the evidence defining a relationship with population growth is not clear and some have even suggested that population growth can possibly impair economic growth (Prskawetz et al., 2007). Others have suggested that falling fertility stimulates per capita growth as a result of increased human capital investments and that the economic consequences of falling fertility are only observed over the long-term through decreasing labour force participation (Bloom et al., 2009; Lee and Mason, 2009). However, what is increasingly recognized as being important is the age structure of the population, whereby the proportion of working-aged cohorts relative to economically inactive cohorts is more relevant for economic growth (Bloom et al., 2003). The importance of working age populations is also reflected in the ART tax modelling approach described earlier because the creation of a child from ART leads to increased government expenses in the short term, and the return on investment in future taxes is not achieved for more than 30 years after these children enter the work force (Svensson et al., 2008; Connolly et al., 2009b).

Another approach to determining whether ART represents good ‘value for money’ is to measure society’s willingness-to-pay for ART. Although it is questionable whether such methods are applicable to fertility treatments, one pilot study did attempt to quantify ART treatment from an ex-post (user-based) perspective and ex-ante (insurance-based) perspective. Using contingent valuation to directly quantify the monetary value of a baby conceived through ART, the study estimated that the implied willingness-to-pay for a baby was $177 730 (2006 $192 410) for potential child bearers in the event that they were infertile, and $1.8 million (2006 $1.9 million) for society to pay for insurance to allow couples access to ART. These values far exceed the cost per live birth following ART treatment suggesting that surplus benefit arises following successful ART outcome (Neumann and Johannesson, 1994).

**Conclusions**

Assisted reproductive technologies are now well-established treatments for many types of subfertility, representing substantial economic and healthcare implications for patients, healthcare providers and society as a whole. Despite this the complex interaction between direct and indirect treatment costs, affordability and consumer and provider behaviour is only starting to be investigated and understood.

The funding and regulation of ART treatment share few general characteristics among countries, ranging from generous, relatively unrestricted public funding in Australia to negligible public funding in the USA and most developing countries. The cost of ART treatment also shows marked variability among countries, generally reflecting the costliness of the underlying healthcare system. While the direct cost of an unsubsidized ART treatment represents a substantial proportion of annual disposable income, the total cost of ART treatment from a national healthcare expenditure perspective is typically less than 0.25%.

The financial burden placed on consumers to pay for treatment, that is how affordable it is, is one of the most important drivers of utilization. Furthermore, affordability has the potential to incentivize clinical practice and consumer behaviour in terms of treatment seeking, types of fertility treatment undertaken and embryo transfer practices. Thus, a lack of financial support through the subsidization of appropriate fertility treatment, not only creates inequities in access to care, but is costly in terms of predisposing to multiple pregnancies.

A greater understanding of the relationship between the cost of ART treatment, utilization and safe clinical practice will not only facilitate equitable access to care for subfertile patients but will also help children born from ART procedures to get the best possible start in life. Given the high estimated return on investment for ART children, it makes clinical as well as economic sense to provide affordable treatment to those who need it.

**Authors’ roles**

The manuscript was developed on behalf of the ESHRE Reproduction and Society Task Force. The three named authors have equally contributed to the writing of the manuscript and managing the review with all other task force members. Information regarding the task force members that have reviewed the manuscript to date can be found on the ESHRE website (http://www.eshre.com/ESHRE/English/Specialty-Groups/Task-forces/TF-Infertility-and-Society/Welcome/page.aspx/688).

The main tasks managed by the three authors included: (1) identifying relevant subject matter for inclusion in the review; (2) conducting literature reviews; (3) analysis of identified data; (4) writing and editing of manuscript and (5) reviewing with other task force members.

**References**


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