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The economic impact of assisted reproductive technology: a review of selected developed countries

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Objective: To compare regulatory and economic aspects of assisted reproductive technologies (ART) in developed countries.

Design: Comparative policy and economic analysis.

Patient(s): Couples undergoing ART treatment in the United States, Canada, United Kingdom, Scandinavia, Japan, and Australia.

Outcome Measure(s): Description of regulatory and financing arrangements, cycle costs, cost-effectiveness ratios, total expenditure, utilization, and price elasticity.

Result(s): Regulation and financing of ART share few general characteristics in developed countries. The cost of treatment reflects the costliness of the underlying healthcare system rather than the regulatory or funding environment. The cost (in 2006 United States dollars) of a standard IVF cycle ranged from \$12,513 in the United States to \$3,956 in Japan. The cost per live birth was highest in the United States and United Kingdom (\$41,132 and \$40,364, respectively) and lowest in Scandinavia and Japan (\$24,485 and \$24,329, respectively). The cost of an IVF cycle after government subsidization ranged from 50% of annual disposable income in the United States to 6% in Australia. The cost of ART treatment did not exceed 0.25% of total healthcare expenditure in any country. Australia and Scandinavia were the only country/region to reach levels of utilization approximating demand, with North America meeting only 24% of estimated demand. Demand displayed variable price elasticity.

Conclusion(s): Assisted reproductive technology is expensive from a patient perspective but not from a societal perspective. Only countries with funding arrangements that minimize out-of-pocket expenses met expected demand. Funding mechanisms should maximize efficiency and equity of access while minimizing the potential harm from multiple births. (Fertil Steril® 2009;91:2281–94. ©2009 by American Society for Reproductive Medicine.)

Key Words: Assisted reproductive technologies, IVF, cost/cost-effectiveness, utilization, regulation, policy

Since the birth of Louise Brown, the world's first IVF baby 30 years ago, an estimated 3.5 million children have been born worldwide after treatment with assisted reproductive technologies (ART) (1). Over the last decade the annual increase in

ART services has been approximately 5%–10% in developed countries (2–7). The combined estimates from the countries reporting to United States and European ART registries alone indicate that 500,000 treatment cycles were undertaken in 2004, resulting in approximately 105,000 deliveries (6, 8). Assisted reproductive technology procedures have evolved to incorporate complex ovarian stimulation protocols, in vitro treatment of gametes including intracytoplasmic sperm injection (ICSI), extended embryo culture, cryopreservation of embryos, and more recently in vitro maturation of oocytes. With live birth rates per initiated cycle of 20%–40% worldwide, ART is now widely accepted as clinically effective in the treatment of many forms of subfertility; however, the economic implications of ART in relation to different healthcare systems and funding models is less appreciated.

Received October 23, 2008; accepted April 13, 2009.

G.M.C. has nothing to disclose. E.A.S. has nothing to disclose. O.I. has nothing to disclose. M.G.C. is a shareholder with IVFAustralia. G.D.A. is the CEO and shareholder of Advanced Reproductive Care.

G.M.C. receives a postgraduate research scholarship from the Australian Government National Health and Medical Research Council (grant no. 401136). G.D.A. receives research funding from EMD Serono and IBSA.

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The aim of this study was to compare economic aspects of ART in selected developed countries, focusing on the costs of treatment, affordability, cost-effectiveness ratios, levels of utilization, price elasticity, and total expenditure. A previous landmark review undertaken by Collins compared economic aspects of ART across a number of developed and developing countries (9). However, to our knowledge, the present study is the first economic review of ART to use a standardized model of national registry data and contemporary country-specific costs to analyze the economics of ART in developed countries.

MATERIALS AND METHODS

Data Collection

The United States (US), Canada, the United Kingdom, Japan, Australia, and Scandinavian countries as a whole (Sweden, Denmark, Finland, Norway, and Iceland) were chosen to represent developed countries with differing regulatory and funding arrangements for ART. A description of the regulatory and funding environment for each country was sourced from professional society web sites, peer-reviewed articles, government publications, and the authors' knowledge. Arrangements as they existed in 2003 have been reported, so as to align ART provision with treatment and utilization data; however, significant changes to the regulatory or funding environment since 2003 have also been noted.

The numbers of autologous (nondonor oocyte or embryo) IVF and ICSI cycles undertaken in 2003 were sourced from national registries and, where possible, supplemented with requests to the data custodians in each country. Donor oocyte cycles were excluded because legislation, surveillance, and charging practices for such procedures vary considerably within and between countries (10–12). Furthermore, because of low utilization and/or limited surveillance, in vitro maturation, preimplantation genetic diagnosis, and surgical sperm collection procedures were excluded, as were surrogacy and gamete intrafallopian transfer cycles. Using these exclusion criteria 12% of US cycles and 3% of European cycles were excluded from the analysis (13, 14). The type of ovarian stimulation was not recorded by most countries, so all cycles were assumed to be stimulated and average medication costs used. Where the numbers of assisted hatching, blastocyst culture, or cryopreservation services were not available, estimates were imputed as the average percentage of IVF embryo transfer (ET) cycles that included these procedures in the remaining countries. Similarly, where the cost of a service was not available (e.g., blastocyst culture for Scandinavia) estimates were imputed as the average percentage of the cost of IVF ET cycles in the remaining countries; for example, the average cost of blastocyst culture in all countries except those of Scandinavia was 8.24% of an IVF ET cycle, therefore the imputed cost of blastocyst culture in Scandinavia was estimated as 8.24% of \$5,549 (\$458).

Treatment costs were sourced from charge surveys conducted by professional bodies, web-based surveys of fertility

clinic charges, peer-reviewed articles, and national medical and pharmaceutical rebate schedules. Healthcare and medical price indices were sourced from national statistics bureaus in each country. These data sources are summarized in Table 1. In addition, country-specific economic indicators and population statistics were sourced from The World Bank, World Development Indicators database (24), the US Census Bureau, Global Population Profile (25), the Organisation for Economic Co-operation and Development (OECD) Economic Outlook Database (26), and the OECD's annual publication, *Taxing Wages* (27). Interbank currency exchange rates for average calendar years were sourced from Oanda (28).

ART Treatment Outcomes and Utilization

A comparative analysis of absolute numbers of cycles and procedures and the associated treatment outcomes was undertaken for initiated fresh and frozen autologous cycles undertaken in 2003. The overall live birth rates per initiated cycle and the multiple birth rates per live birth delivery were then computed. The estimated cumulative delivery rates with at least one live birth were calculated as the number of live births from fresh and frozen ETs divided by the number of follicular aspirations. Utilization of ART was calculated as the number of fresh and frozen cycles initiated per million population and per million women of reproductive age per annum in each country/region (24, 25).

ART Costs and Cost-Effectiveness Ratios

The estimated average cost of partial and complete treatment cycles and associated procedures were estimated from the sources shown in Table 1. All costs were expressed in 2006 US dollars (USD 2006) using country-specific healthcare or medical price indices and average annual interbank currency exchange rates. For example, the cost of a standard cycle in Scandinavia was €4,275 in 2004. With a weighted price index for the "health" basket in 2004–2006 for the five Nordic Council countries of 3.3294% and a currency conversion rate to USD of 1.25622, the cost a standard cycle becomes USD 2006 \$5,549.

Costs reflected the direct healthcare costs of providing ART treatment up until a pregnancy was achieved, including public and private sector costs and charges and patient out-of-pocket expenses. The costs included planning and management of treatment cycles, ovarian stimulation and monitoring, ultrasound scanning, sperm preparation, follicular aspiration and ET, hospital theatre and accommodation, anaesthetists' charges, embryology services (including blastocyst culture, assisted hatching, and ICSI), and cryopreservation of supernumerary embryos inclusive of 1 year of storage fees. Fertility workup procedures and downstream costs associated with perinatal care and multiple births were not included.

Country-specific cost-effectiveness ratios, defined as the average cost per live birth from fresh and frozen embryo

TABLE 1**Source of treatment numbers, outcomes, and costs.**

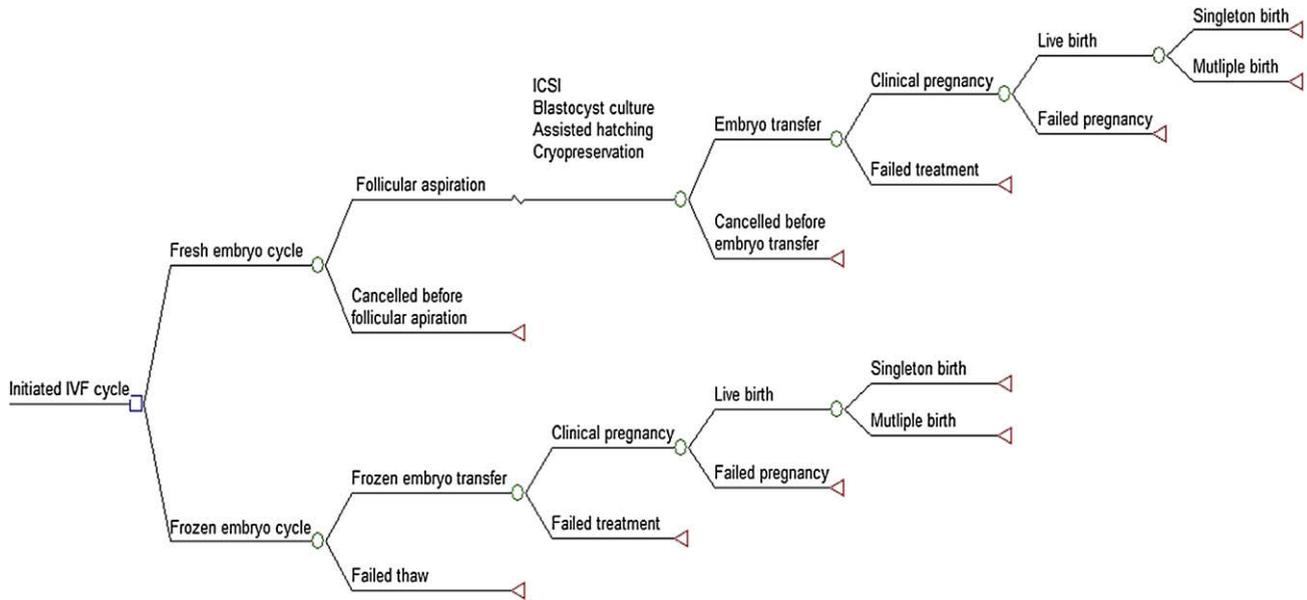
Country or region	2003 ART treatment numbers and outcomes	ART treatment costs	Original currency and year of cost estimates	Source of healthcare and medical price indices
United States	US registry report, supplemented with additional information requested from the US ART registry (13)	Average costs for IVF in a national network of clinics supplemented by a web-based survey of fertility clinics (15, 16)	USD 2004	US Department of Labor, Bureau of Labor Statistics
Canada	Canadian registry report, supplemented with additional information requested from the Canadian ART registry (17).	Web survey of fertility clinics; 21 of 28 clinics listed on the Canadian Fertility and Andrology Society web site were surveyed for fee information (18)	CAD 2006	Statistics Canada
United Kingdom	European registry report, supplemented with additional information requested from the Human Fertilisation and Embryology Authority (HFEA) ART registry (14)	Web survey of fertility clinics; 20 of 73 clinics listed on the HFEA web site were surveyed for fee information (19)	GPD 2006	United Kingdom Statistics Authority, Office of National Statistics
Scandinavia	European registry report, supplemented with additional information requested from the Swedish ART registry (14)	Published estimates (20)	Euro 2004	Weighted averages from Statistics Denmark, Statistics Sweden, Statistics Norway, Statistics Finland, and Statistics Iceland
Japan	Japanese Society of Obstetrics and Gynaecology annual reports collated by the authors (Ishihara O, personal correspondence, July 2007)	Web-based survey of fertility clinics and Japanese newspaper articles (21, 22; Ishihara O, personal correspondence, July 2007)	JPY 2006	Japan Ministry of Internal Affairs and Communication, Statistics Bureau
Australia	Request to the Australian and New Zealand Assisted Reproductive Database	Published estimates (23)	AUD 2005	Australian Bureau of Statistics

Note: USD = United States dollars; CAD = Canadian dollars; GPD = Great Britain pound; JPY = Japanese yen; AUD = Australian dollar.

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FIGURE 1

Decision tree for the calculation of cost-effectiveness ratios.

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cycles, were calculated using a decision tree model. The simplified model is presented in Figure 1. The model was constructed to represent significant clinical and economic outcomes from fresh and frozen embryo treatment cycles, commencing from an initiated treatment cycle through to a pregnancy leading to a live birth. Partial cycles included cycles discontinued before follicular aspiration and ET. Procedures for ICSI, blastocyst culture, assisted hatching, and cryopreservation of supernumerary embryos were included. The numbers of cycles reaching each stage of the model were multiplied by the corresponding estimated cost of each partial and complete cycle type. The average costs per live birth were calculated by summing the total costs for each cycle type and dividing by the number of live births. A live birth was defined as the delivery of at least one live-born infant, with the birth of a singleton, twin, or other multiple pregnancy being counted as one live birth. Because a woman may undergo more than one cycle of treatment in a given year, she could contribute more than one fresh or frozen embryo cycle to an annual ART registry cohort. Therefore the cost-effectiveness ratios were necessarily a reflection of the number of cycles undertaken, rather than the number of women undergoing treatment.

Measures of Economic Impact

Measures of the economic burden of direct ART treatment costs in each country were expressed from a societal and patient perspective. From a societal perspective the relative affordability of treatment was calculated as the cost of a standard IVF cycle as a percentage of gross national income (GNI) per capita in 2006 (24).

From a patient perspective, the relative affordability of treatment was calculated as the cost of a standard IVF cycle as a percentage of disposable income for a single worker without children earning 100% of average earnings. To calculate disposable income (i.e., an approximation of funds available for consumption), total labor costs were multiplied by the country-specific OEDC tax wedge. Labor costs included gross wage earnings plus employers' social security contributions and payroll tax. The tax wedge is the sum of all personal income tax, employee and employer social security contributions, and payroll taxes less any cash benefits from government welfare programs, expressed as a percentage of labor costs (27, 29). For example, the average labor costs in the United States in 2006 were \$35,045, and the percentage of labor costs represented by the tax wedge was 28.9% (\$10,128). Therefore, the disposable income of an average worker in the United States was calculated as \$24,917 by subtracting the percentage of labor costs represented by the tax wedge from the average labor costs. The weighted average tax wedge and labor cost for Scandinavian workers was based on the proportion of the labor force in each of the five countries (26). Labor costs and disposable income were expressed in USD 2006 using purchasing power parity to equalize the purchasing power between currencies. The gross cost of a standard cycle before government subsidization as a percentage of disposable income was then calculated.

The effect of government subsidization on the cost of treatment was estimated by applying the rate of publicly funded cycles to the cost of a standard cycle and then estimating the residual level of copayments. This provided an estimate of the average price to consumers for a standard IVF cycle

in each country or region. However, because private funding of healthcare through insurance (employer and private) and managed care models is so fundamental to the US healthcare system—more so than any of the other countries surveyed—the effect of insurance on the cost of ART was also included for US estimates of consumer price. The estimates of the number of cycles directly funded by consumers in each country were sourced from multiple sources, including professional organization web sites, direct communication with national health departments, government reports, estimates from pharmaceutical companies, peer-reviewed articles, and International Federation of Fertility Society surveys (11, 12).

The total cost of ART treatment was calculated by summing all direct treatment costs and expressing them as a percentage of total public and private healthcare expenditure in each country (24).

An important aspect of the demand for a good or service is how much the quantity demanded changes when the consumer price changes. Generally, the demand for healthcare services declines as the consumer price increases (30). The economic measure of this responsiveness to price is the price elasticity of demand (PED). This measure allows the changes in demand and revenue of a good or service to be predicted with changes in the consumer price and is often used by policy makers before embarking on legislation that may alter consumer price. The formula for the PED is:

$$\frac{\% \text{ change in quantity demanded } (Q)}{\% \text{ change in price } (P)}$$

The PED was estimated using the average consumer price of a standard IVF cycle and the utilization of initiated fresh autologous cycles for the countries surveyed. The percentage rise and fall of Q and P was calculated on the basis of the mid-points of the change. This formula for calculating the PED results in what is known as the *Arc* PED. It was used because ART utilization and price exhibited large variations among the countries surveyed, and the price of ART could theoretically increase or decrease. Thus, the PED equation used was:

$$\text{PED} = \frac{\frac{Q_2 - Q_1}{(Q_1 + Q_2)/2}}{\frac{P_2 - P_1}{(P_1 + P_2)/2}}$$

The PED is not assigned units of measure, and the negative sign is often omitted. Demand is considered to be price inelastic whenever the percentage change in price leads to a smaller percentage change in quantity demanded, giving a PED of 0 and -1 . When elasticity is exactly -1 the proportionate changes in price and quantity are the same. Demand is considered to be price elastic whenever the percentage change in price leads to a larger change in demand, giving a PED between -1 and $-\infty$ (31).

Ethics Approval

This study was approved by the Social/Health Research Human Research Ethics Advisory Panel, University of New South Wales, Australia.

RESULTS

Provision of ART Services

Without exception, the regulation, provision, and funding of ART services differed among the countries surveyed (Table 2). Regulation ranged from minimal legislation in the United States, Canada, some Scandinavian countries, and Japan to relatively highly regulated environments in the United Kingdom and parts of Australia and Scandinavia. As would be expected in a rapidly evolving field that has strong sociocultural associations, legislation has continued to evolve since 2003, becoming more or less restrictive in the countries reviewed. Funding arrangements for ART services also varied widely, from no public funding in the United States and Japan to unrestricted and unlimited public reimbursement with copayments in Australia.

ART Treatment Number and Outcomes

The numbers of fresh and frozen embryo treatment cycles, additional procedures such as ICSI and blastocyst culture, and the outcomes from these treatments are summarized in Table 3. The largest absolute numbers of cycles and procedures were in the United States, followed by Japan, the United Kingdom, Scandinavia, Australia, and Canada. The United States had the highest live birth rate per initiated fresh cycle (28.4%) but also the highest multiple birth delivery rate (34.2%). In contrast, Japan had the lowest live birth rate per initiated fresh cycle (13.7%) but also had the lowest multiple-birth rate (17.1%). The estimated cumulative live birth rate per follicular aspiration (capturing both fresh and frozen embryo transfer cycles) was highest in the United States at 37.7%, compared with 20.2% in Japan. Scandinavia had the only countries that achieved multiple birth rates less than their delivery rates per initiated fresh cycle. The disparity in treatment outcomes reflects differences in clinical practice and ART patient populations between the countries, therefore caution must be used when drawing conclusions about the effectiveness of ART treatment in different regions of the world (45).

ART Utilization

In conjunction with the regulatory and funding framework, the utilization of ART services depends on demand, availability, cost, and consumer price. Each of these components interrelates to determine the level of utilization of ART. The number of autologous ART cycles initiated per million population and per million women of reproductive age per annum is presented in Figure 2. Australia and Scandinavia had the highest levels of utilization at 1,574 and 1,465 cycles per million population, respectively; this was approximately four to five times the utilization in the United States and Canada, which was 373 and 311 cycles per million population, respectively. Demand for ART treatment has been estimated by the European Society of Human Reproduction and Embryology as 1,500 couples per million population (46). Although couples may undergo more than one cycle in a given year, 1,500 cycles per annum is considered a conservative underestimate (9, 36). Therefore, Australia and

TABLE 2

Regulation and funding in 2003.

Country/region	Regulation	Funding and provision
United States	No federal legislation governing fertility treatment except for gamete donation, which is regulated by the US Food and Drug Administration (FDA). Fertility clinics are required to register with the FDA and to report annual live birth success rates to the Centers for Disease Control and Prevention. Individual clinic success rates are reported annually by the American Society for Reproductive Medicine (ASRM)/Society for Assisted Reproductive Technology (SART). Embryology laboratories are required to be certified with biannual on-site inspections through the College of American Pathologists/ASRM or Joint Commission on Accreditation of Hospital Organizations. Practice guidelines are provided by SART and the ASRM.	No federal government reimbursement of ART procedures or medications in 2003. State insurance laws ensured that 13 states had mandates for fertility treatment coverage by third-party payers, but only 5 states included IVF treatment in their schedules. Fifteen states now have mandates to either cover or offer coverage for fertility treatment. Treatment primarily offered through private clinics and funded directly by patients or through finance companies (32–34; Adamson GD, personal communication, June 2008).
Canada	No federal legislation or professional practice guidelines governing fertility treatment existed in 2003. The Assisted Human Reproduction Act was passed in 2004 to develop a legislative framework. Assisted Human Reproduction Canada is responsible for administering and enforcing the Act. In 2008, the Society of Obstetricians and Gynecologists of Canada and the Canadian Fertility and Andrology Society published guidelines for the number of embryos to transfer after IVF.	No federal government reimbursement of ART procedures or medications. The Ontario Health Insurance Plan pays for three IVF cycles, excluding drugs, in the case of complete bilateral blocked fallopian tubes. Treatment primarily offered through private clinics and funded directly by patients (10, 35–37).
UK	The Human Fertilisation and Embryology Authority (HFEA) is the statutory licensing body responsible for enforcing activities associated with ART. Practice guidelines provided by the HFEA.	Restricted government funding for ART procedures provided through the National Health Service (NHS) dependent on the local Health Authority or Primary Care Trust (PCT). The National Institute for Health and Clinical Excellence guidelines published in 2004 recommend that three IVF cycles be offered on the NHS. A survey of English PCTs in 2007 found that 100 of the 151 trusts offered one IVF cycle, 35 offered two cycles, and 9 offered three cycles. Four trusts did not provide NHS cycles at the time of the survey. Treatment offered through NHS and private clinics. Most ART treatment funded directly by patients (19, 38, 39).
Scandinavia	ART legislation differs considerably among countries, ranging from the no legislation in Finland to relatively restrictive legislation in Norway. Regulatory changes have taken effect in a number of countries since 2003.	Government funding of procedures or medications for ART services provided in all countries; however, funding arrangements and restrictions differ among countries. Treatment offered through public and private clinics, characterized by long waiting lists in public clinics. Approximately 50% of cycles funded by the public sector (40–42).
Japan	No federal legislation governing fertility treatment. Fertility clinics required to register with Japan Society of Obstetrics and Gynaecology (JSOG). Practice guidelines provided by JSOG.	No government reimbursement of ART procedures or medications for ART services in 2003. Some federal reimbursement for fertility treatment was introduced in 2006; 100,000 JPY was paid per cycle for up to two cycles annually for 2 years, means tested on annual household income. In 2007, the income threshold and number of years of subsidization was increased. Treatment primarily offered through private clinics and funded directly by patients (43; Ishihara O, personal correspondence, July 2007).
Australia	Legislation governing fertility treatment determined at the state and territory level. Fertility clinics using embryos must be accredited by the Reproductive Technology Accreditation Committee (RTAC) of the Fertility Society of Australia (FSA). Practice guidelines provided by the National Health and Medical Research Council and the RTAC.	Federal funding for procedures and medications provided for an unlimited number of ART cycles deemed “clinically relevant” and in line with state and territory legislation. Copayments required but insurance through third-party payers is available. Treatment primarily offered through private clinics (11, 12, 44).

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TABLE 3
Numbers of autologous ART treatment cycles, procedures, and outcomes in 2003.

Variable	United States ^a	Canada ^b	United Kingdom ^c	Scandinavia ^d	Japan ^e	Australia ^f
Fresh embryo cycles						
Initiated cycles	91,032	7,532	28,602	28,141	77,033	19,444
Follicular aspirations	79,602	6,751	26,578	26,918	72,741	17,568
ETs	74,296	6,300	24,652	24,147	55,752	15,329
ICSI	44,259	3,523	12,157	11,564	36,663	9,825
Assisted hatching	34,649	1,457	90	1,160 ^g	2,679 ^g	677
Blastocyst culture	14,339	1,361	1,047	3,877 ^g	8,952 ^g	2,613
Cryopreservation + 1 y storage	23,136	2,359	8,037	10,228 ^g	23,615 ^g	9,207
Clinical pregnancies	31,348	2,352	7,459	7,815	15,806	4,522
Live birth deliveries	25,775	1,766	6,520	6,038	10,524	3,412
Singleton live birth deliveries	16,959	1,218	4,854	4,944	8,720	2,728
Live birth rate per initiated cycle (%)	28.4	23.9	22.8	21.5	13.7	17.6
Multiple birth rate per delivery (%)	34.2	31.0	25.6	18.1	17.1	20.0
Frozen embryo cycles						
Initiated cycles	17,517	2,309	6,868	7,631	24,352	11,870
ETs	15,726	1,993	6,081	6,267	19,545	10,877
Clinical pregnancies	5,381	488	1,208	1,384	6,189	2,196
Live birth deliveries	4,246	367	1,062	1,041	4,143	1,630
Singleton live birth deliveries	3,172	268	892	908	3,604	1,424
Live birth rate per initiated cycle (%)	24.2	16.1	15.5	13.6	17.0	13.7
Multiple birth rate per delivery (%)	25.3	27.0	16.0	12.8	13.0	12.6
Cumulative delivery rate with at least one live birth ^h (%)	37.7	31.6	28.5	26.3	20.2	28.7
Overall multiple birth delivery rate ⁱ (%)	32.9	30.3	24.2	17.3	16.0	17.7

^a United States: Initiated cycles contain gamete intrafallopian transfer/zygote intrafallopian transfer cycles (<1% of initiated cycles). Delivery status was unknown in 0.9% of clinical pregnancies resulting from fresh cycles; therefore, 232 cycles were omitted from the live birth rate numerator and denominator.

^b Canada: 139 and 25 clinical pregnancies resulting from fresh and frozen embryo cycles, respectively, had an unknown delivery status and were therefore omitted from the live birth rate numerator and denominator.

^c United Kingdom: Multiple birth rates were obtained by applying the multiple birth rates reported to the European Society of Human Reproduction and Embryology (ESHRE) (14). The number of ICSI procedures was estimated as the number of ICSI cycles reported to ESHRE (14).

^d Scandinavia: The ESHRE registry report (14) did not state whether "deliveries" included live births and still births; therefore, the number of "deliveries" was used as a proxy for live births. The ESHRE registry report (14) did not report quadruplet deliveries; therefore, the multiple live birth rate may be an underestimate. The ESHRE registry report (14) did not report mixed IVF/ICSI cycles or natural cycles (estimated to be <1% of cycles). Iceland did not report the number of initiated fresh IVF or ICSI cycles; therefore, these were imputed from the average number of cycles not reaching follicular aspiration from the remaining four Scandinavian countries. Finland did not report the number of initiated frozen embryo cycles; therefore, this figure was imputed from the average number of cycles not reaching ET from the remaining four Scandinavian countries.

^e Japan: The singleton and multiple birth rates were determined from the multiple pregnancy rates.

^f Australia: 11 and 9 clinical pregnancies resulting from fresh and frozen embryo cycles, respectively, had an unknown delivery status and were therefore omitted from the live birth rate numerator and denominator.

^g Denotes imputed values based on the average percentage of ET cycles in the remaining countries.

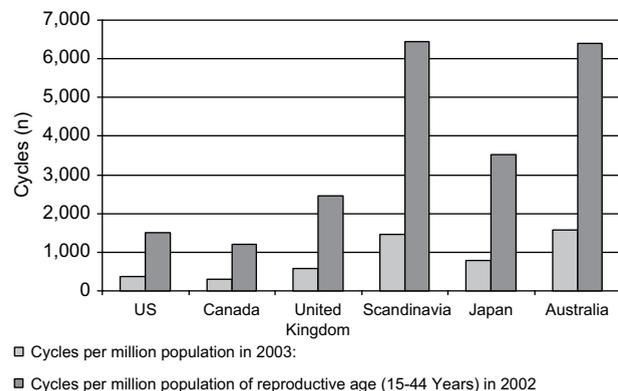
^h Cumulative delivery rates with at least one live birth were estimated as the number of live births from fresh and frozen embryo transfers divided by the number of follicular aspirations.

ⁱ Overall multiple birth delivery rates were calculated as the number of multiple births from fresh and frozen embryo transfers divided by the total number of live birth deliveries.

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FIGURE 2

Level of utilization of autologous ART treatment cycles in 2003.



Note: Population statistics sourced from The World Bank, World Development Indicators database (24) and the US Census Bureau, Global Population Profile (25).

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Scandinavia were the only country and region to meet this benchmark. Canada and the United States had the lowest levels of utilization, resulting in an unmet demand of 365,000 cycles per annum; that is to say, only 24% of demand for ART treatment cycles in North America was met in 2003.

ART Treatment Costs

The average cost of a standard IVF cycle was \$12,513 in the United States, \$8,500 in Canada, \$6,534 in the United Kingdom, \$5,645 in Australia, \$5,549 in Scandinavia, and \$3,956 in Japan. The breakdown of treatment costs into medications and services/procedures is summarized in Table 4.

Economic Impact of ART Treatment

Affordability In terms of the magnitude of the economic burden ART treatment costs place on the economy of a country (i.e., how affordable it is to a society as a whole), it is useful to examine the cost of a cycle as a percentage of GNI per capita. This review found that the cost of a standard IVF cycle ranged from 28% of GNI per capita in the United States to 10% of GNI per capita in Japan. The variation mainly reflected the relative costliness of treatment in these countries with all countries having high percentages of GNI per capita - ranging from a mean of \$49,722 for the Scandinavian countries to \$35,860 for Australia, compared with \$38,190 for all high-income OECD countries. The average costs of a standard fresh IVF cycle and the cost as a percentage of GNI per capita are presented in Figure 3.

Given that the economic burden for financing ART is spread unevenly between the public and private sectors in the countries reviewed, it is also useful to examine the patient out-of-pocket expenses of a cycle as a percentage of average disposable income before and after government subsidization, thus giving an indication of the affordability of treatment from a patient's perspective (the consumer price). Before the effect of any type of government subsidization, the gross cost of a standard IVF cycle was highest in the United States at 50% of an individual's annual disposable income, compared with 12% in Japan. After accounting for government subsidies, the resultant net patient cost of a standard IVF cycle was unchanged in the United States and Japan owing to there being no public funding for ART treatment. However, after taking in to account the inherent role of insurance in the US healthcare system, the cost of a standard IVF cycle as a percentage of disposable income decreased from 50% to 44% in the United States. The greatest affect of subsidization was in Australia, with a 71% reduction in the cost of a standard cycle as a percentage of

TABLE 4

Costs of ART treatment cycles and procedures (USD 2006).

Variable	United States	Canada	United Kingdom	Scandinavia	Japan	Australia
Fresh transfer cycle	12,513 ^a	8,500	6,534	5,549	3,956	5,645
Medications	(3,154)	(3,528)	(1,758)	(1,573)	(516)	(999)
Services/procedures	(9,358)	(4,972)	(4,776)	(3,976)	(3,440)	(4,646)
Frozen-thawed transfer cycle	3035	2,380	1,560	1,347	1,108	1,648
ICSI	1,626	1,172	1,339	614	860	469
Assisted hatching	705	349	675	339 ^b	271	207
Blastocyst culture	379	247	678	458 ^b	632	508
Cryopreservation +1 y storage	1,138	590	579	457 ^b	452	274

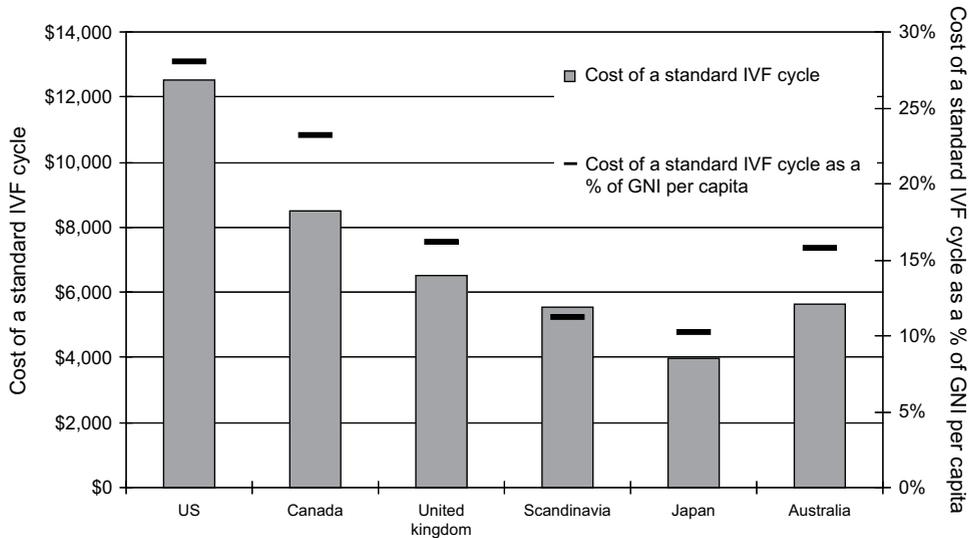
^a The US medication and service/procedures cost does not sum to the total cost of a fresh transfer cycle because of rounding.

^b Denotes imputed value calculated as the percentage of the cost of an embryo transfer cycle in the remaining countries.

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FIGURE 3

Average cost of a standard fresh IVF cycle, and as a percentage of GNI per capita (USD 2006).



Note: GNI per capita sourced from The World Bank Group, World Development Indicators database (24).

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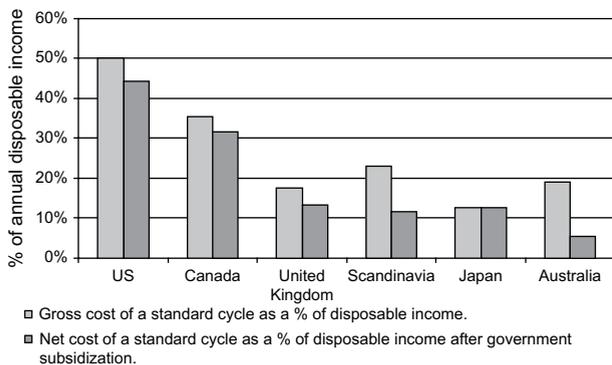
disposable income, from 19% before government subsidization to 6% after government subsidization (Fig. 4).

ART Costs Relative to Total Healthcare Expenditure In addition to the cost of an individual treatment cycle, the economic impact of ART is also related to the volume of treatments and

services undertaken and how much of the total healthcare dollar this consumes. The total cost of all ART treatments, including cancelled cycles and additional services, as a percentage of total public and private healthcare expenditure in 2003, is presented in Figure 5. Treatment with ART amounted to $\leq 0.25\%$ of total healthcare expenditure in all countries, with Australia having the highest consumption at 0.25% and the United States having the lowest at 0.06%. These percentages largely reflect the level of utilization of ART services in each country or region.

FIGURE 4

Average cost of a standard IVF cycle as a percentage of annual disposable income (USD 2006).



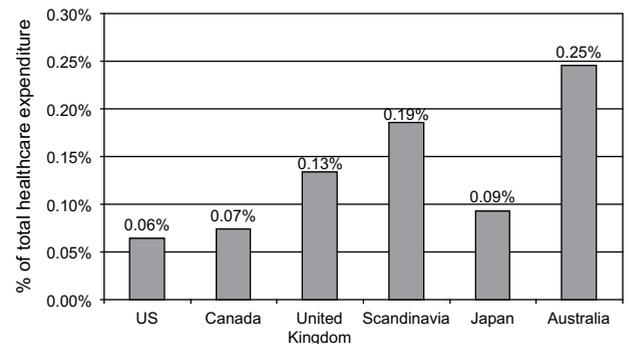
Note:

- Annual disposable income is based on a single person at 100% of average earnings with no dependents (27).
- 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.
- In the US, there is negligible government subsidization for ART, however, the central role of private insurance in the US was included in the analysis, reducing the average price of a standard cycle by 12%.

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FIGURE 5

Total ART treatment costs as a percentage of total healthcare expenditure (USD 2003).



Note:

Total healthcare expenditure was sourced from The World Bank, World Development Indicators database (24).

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TABLE 5

Estimates of the price elasticity of demand (PED) for ART in developed countries.

Country/region	Utilization (Q) (cpm ^a)	Price (P) (USD 2006)	% change in (Q)	% change in (P)	PED
Australia	977	1,658	-0.16	-0.50	0.33
Scandinavia	1,153	2,775	0.63	-0.35	-1.78
Japan	603	3,956	0.24	-0.21	-1.12
United Kingdom	474	4,901	0.66	-0.43	-1.55
Canada	238	7,565	-0.27	-0.37	0.73
US	313	11,011			

^a cpm denotes initiated fresh cycles per million population.

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Price Elasticity of Demand As described in the Materials and Methods section, the economic measure of the responsiveness of demand to price is the PED. This measure allows the changes in demand and revenue of a good to be predicted with changes in price. Demand is price inelastic whenever the percentage change in price leads to a smaller percentage change in quantity demanded (i.e., demand responds to changing price by a smaller proportion than the change in price, giving a PED of 0 and -1), and demand is price elastic whenever the percentage change in price leads to a larger change in demand (i.e., the quantity demanded is highly responsive to price, giving a PED between -1 and -∞).

Using the average consumer price of a standard IVF cycle and utilization of fresh cycles for the countries surveyed, the PED for autologous ART was estimated (Table 5). Ideally PED is calculated when all market factors other than price are held constant. Although this was not the case in this study, the ART markets surveyed all represented growth industries in highly developed countries.

The results indicate that the PED for ART in developed countries was relatively elastic in the mid-range prices for a fresh cycle between \$2,775 and \$7,565 but less elastic at the upper and lower price ranges. For example, a 10% reduction in price in the range from \$3,956 to \$2,775 would theoretically be associated with a 17.8% increase in demand. This contrasts with estimates from the United States, where the consumer price is substantially higher and one cycle represents close to 45% of annual disposable income; therefore, it would be predicted that a small drop in price would not substantially increase demand.

The PED also allows changes in revenue to be predicted when prices rise or fall. The general rule is that if PED is elastic, a rise in price will lead to less spending by consumers, whereas a fall in price will lead to more spending by consumers. The opposite is true for PEDs that are inelastic (31). Therefore, a small reduction in IVF prices around the mid-range (\$2,775-\$7,565 per cycle) would be expected to increase consumer spending on IVF (revenue) because the percentage change in quantity demanded is greater than that in the price.

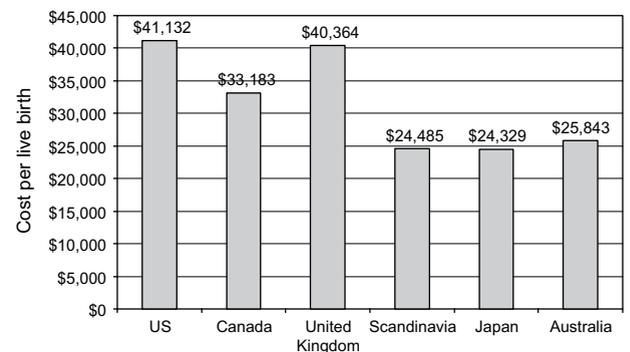
Factors other than price impact on the demand of healthcare services, and in particular ART, which is fundamentally a discretionary good. The observational data used to calculate the PED in this study were not controlled for such factors. Of particular importance is the income of different patient populations. Healthcare is generally income elastic, so that as incomes rise the quantity of healthcare consumed rises more than proportionately. The countries chosen for this review are all high-income countries; however, different patient groups within each country would exhibit different patterns of elasticity of demand and income. Other factors that may impact utilization of fresh cycles include the availability and cost of alternate fertility treatments, legislation, access to fertility clinics, patient age, and ART clinical practice per se (e.g., the approach taken to using frozen embryo cycles as an adjunct to fresh cycles).

Cost-Effectiveness Ratios for ART

The cost per live birth reflects the relationship between the cost of treatment and the success of treatment and is often referred to as the cost-effectiveness ratio. The average costs per

FIGURE 6

Cost per live birth in 2003 for autologous ART treatment cycles (USD 2006).



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live birth are presented in Figure 6. The cost per live birth was highest in the United States at \$41,132 per live birth and lowest in Japan at \$24,329. The average cost per live birth for all countries combined was \$32,727.

DISCUSSION

The regulation and financing of ART in developed countries share few general characteristics and continue to evolve in response to technologic advances, sociocultural pressures, and a trend to later childbearing. The cost and funding of ART are typical of the underlying healthcare systems in each of the countries reviewed, reflecting the varying degrees of public and private responsibility for purchasing healthcare and total healthcare expenditure (47).

The cost of treatment in the United States was substantially higher than in any of the other countries reviewed, reflecting the high cost of healthcare in the United States, with a standard fresh cycle costing \$12,513. The United States has by far the most expensive healthcare system in the world, on the basis of expenditure per capita and total expenditure as a percentage of gross domestic product. The United States spends more than twice the OECD average per capita on healthcare and almost three times as much per capita as Japan (47). High medical technology, drug, and medico-legal costs are partly responsible, together with high administrative costs resulting from the complex, multiple-layer payer system and a shift to for-profit healthcare providers (48, 49). Therefore, ART costs in the United States, although higher than those in other countries, are a reflection of the overall costliness of the US healthcare system rather than a uniquely highly priced service.

In contrast, Japan had the lowest ART costs, with a standard fresh IVF cycle costing \$3,956. This reflects Japan's relatively low per capita and total healthcare spending. The reasons for Japan's relatively inexpensive healthcare system include social factors, such as good general health and consumer preferences for conservative treatment, along with low costs of surgery, medical technology, drugs, and personnel. A comprehensive and mandatory fee schedule officiated by the Japanese government is also an important factor in Japan's low health spending (50–52). The costliness of treatment in the remaining countries fell between the extremes of the United States and Japan, generally reflecting relative healthcare expenditure per capita (47).

There was no clear relationship between the level of regulation and public funding of ART and the costliness of an episode of ART treatment (regardless of the payer of the treatment). For example, the United States and Japan had the highest and lowest cost of treatment, respectively, but both countries were the least regulated and offered almost no public reimbursement of treatment costs.

A combination of the level of public funding and the burden placed on patients to pay for treatment was the main driver of utilization. Higher levels of utilization were found in countries with low out-of-pocket expenses, either through low treatment

costs (as was the case in Japan) or generous public funding (as was the case in Australia and Scandinavia). The results from this survey also suggest that prices for an IVF cycle of between \$2,775 and \$7,565 are relatively elastic, whereas prices at the extreme (\$1,659 and \$11,011) are inelastic. This pattern of elasticity has potential implications for financing and pricing arrangements to optimize ART utilization. However more empirical evidence is needed on the impact of users charges on demand and clinical practice in different patient groups.

Even in countries with high levels of utilization, the total direct costs of ART did not exceed 0.25% of public and private expenditure on healthcare, indicating that the economic burden of ART treatment to society as a whole is not substantial. This is also supported by a number of cost analyses of ART as part of medical insurance plans (53–55). However, when the economic burden to pay for treatment is placed on the individual, the cost of just one standard treatment cycle consumes a substantial amount of individual disposable income, especially in countries without any government subsidization. In the United States the cost of one standard cycle consumed on average 50% of an average worker's annual disposable income, compared with approximately 20% in Scandinavia, the United Kingdom, and Australia and 12% in Japan. However, in a number of countries government subsidization substantially reduced the out-of-pocket expense of ART treatment. For example, because of partial federal funding for an unlimited number of cycles in Australia, the average cost of a standard cycle as a percentage of disposable income decreased from 19% to 6% of average annual disposable income. However, it should be noted that in most countries where there is some form of government subsidy, it is limited to a number of cycles, and therefore patients are either fully subsidized or pay the full cost for a cycle.

The type of healthcare system and the level of expenditure on health does not always equate to efficiency and equity of healthcare delivery (56, 57). Policy and non-policy drivers also play a role in outcomes. As fertility treatment becomes more successful and an increasing proportion of society view IVF as a mainstream treatment, more public or third-party payer financing of fertility treatment is becoming available (10, 58). Treatment with ART is even being considered by demographers as a means for raising fertility rates in developed countries (59, 60). In an attempt to provide more equitable access and to reduce the high incidence of multiple births from ART treatment, Belgium has become the first country to tie public funding to the number of embryos transferred, with reports suggesting that this has led to a reduction in the multiple birth rate to less than 10%, without substantially affecting the overall pregnancy rate (41, 61).

The mean direct cost per live birth for all countries combined was \$32,727, ranging from \$24,329 in Japan to \$41,132 in the United States. Whether this represents good "value for money" depends on a society's willingness-to-pay for a baby born after ART treatment. One study that attempted to directly quantify the monetary value of a statistical baby

conceived through ART found that the implied willingness-to-pay for a baby was \$177,730 (USD 2006 \$241,713) for potential child-bearers in the event that they were infertile, and \$1.8 million (USD 2006 \$2.4 million) for society to pay for insurance to allow couples access to ART (62). Therefore, the cost per live birth for the countries reviewed in this study fell well below the range of what is considered value-for-money in healthcare. Furthermore, the cost of ART treatment is insignificant compared with the lifetime tax contribution of ART children. A recent study calculated that the lifetime net taxes paid from a child relative to the child's initial ART investment represented a 700% net return to the government in discounted US dollars from fully employed individuals. This suggests that removing barriers to IVF would have positive tax benefits for the government, notwithstanding its beneficial effect on overall economic growth (63).

Fertility treatments including ART carry with them significant indirect costs due to the increased risk of maternal and infant morbidity associated with the high incidence of multiple births after such treatment. The perinatal costs of multiple births after ART have themselves been shown to outweigh the cost of ART treatment (64). Furthermore, it is well documented that perinatal costs associated with multiple births are only an indication of the longer-term medical, education, and social costs associated with such births (65–70). The multiple birth delivery rates varied considerably between the countries reviewed, ranging from 33% and 30% in the United States and Canada, respectively, to 16% in Japan. Part of the reason for such discrepancies might be the burden placed on individuals in markets such as the United States and Canada to finance their own treatment, which places a strong financial incentive to achieve success in a limited number of cycles, theoretically leading to the transfer of multiple embryos. In addition, there is pressure on clinics operating in highly competitive markets to emphasize pregnancy rates as successful treatment, rather than singleton live birth rates (71). This observation is underpinned by evidence suggesting that state-mandated insurance coverage for ART in the United States is associated with increased utilization and lower multiple birth delivery rates; however, whether this observation is due to differences in embryo transfer practices or patient characteristics is still unclear (72–74).

It has been shown in countries such as Australia and Sweden that a meaningful level of public funding of ART achieves the shared goals of more ART babies born, coupled with lower multiple-birth rates (7, 41). It is unreasonable to expect couples to embrace single embryo transfer and the concomitant lower pregnancy rates without subsidizing the substantial economic burden of ART treatment (75–81). An appropriate mix of public and private funding minimizes the morbidity and costs associated with multiple births while protecting the reproductive rights of couples and the welfare of ART children.

In conclusion, the approach taken to regulate and finance ART in developed countries is diverse; however, the trend seems to be toward providing some level of public financing.

Despite the variation in the cost of treatment among the countries reviewed, ART is expensive from an individual's perspective but not in terms of national healthcare expenditure. The financial burden placed on patients to pay for treatment was the most important driver of utilization, with only Scandinavia and Australia meeting levels of utilization that approximate demand. In terms of the cost per live birth, ART represents value-for-money to society, especially if the level of multiple births is minimized. Funding bodies have a responsibility to ensure that ART services are funded in such a way that not only maximizes efficiency and equity of access but also secures the safety of children born from such techniques.

Acknowledgments: The authors thank the fertility clinics of each country for providing data to national and regional ART registries.

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