Health economic evaluations of medical devices in the People’s Republic of China: A systematic literature review

Background: The objective of this study is to identify and review the methodological quality of health economic evaluations of medical devices performed in the People’s Republic of China. To our knowledge, no such investigations have been performed to date.

Methods: A systematic literature review involving searches of Medline, Medline In-Process, the National Health Service Economic Evaluation Database, the Cost-Effectiveness Analysis Registry of the Tufts Medical Center, and the Wanfang Database was performed. The search spanned the period from 1990 to 2013. Studies on health economic evaluations of medical devices, in-vitro diagnostics, procedures, and the use of medical devices in Chinese health care settings were included. Full-text articles and conference abstracts in English and Chinese were included.

Results: Fifty-seven publications were included, 26 (46%) of which were in English and 31 (54%) of which were in Chinese. The included publications covered a wide range of clinical areas, such as surgery (n=23, 40%), screening (n=9, 16%), imaging use (n=6, 11%), kidney intervention (n=4, 7%), and nine other technological areas. Most of the studies (n=31, 54%) were cost analyses. Among the others, 13 (50%) studies used modeling, and another 13 (50%) were within-trial evaluations. Among studies that used modeling, eleven (85%) conducted sensitivity analyses, six of which had one-way sensitivity analysis, whereas one conducted both one-way and two-way sensitivity analyses; four of these eleven modeling-based analyses included probabilistic sensitivity analyses. The incremental cost-effectiveness ratio was reported in ten (18%) studies, eight of which were screening studies. The remaining two modeling studies were in areas of imaging and oncology.

Conclusion: This study indicates that there are major limitations and deficiencies in the health economic evaluations on medical devices performed in the People’s Republic of China. Further efforts are required from different stakeholders – academic, governmental, and privatized – to improve health economic research capacity and to put it to use when informative decisions are made in the health care setting.

Keywords: health economics, cost-effectiveness analysis, cost–utility analysis, cost–consequences analysis, medical devices, People’s Republic of China

Introduction

Health economics helps to compare different health technologies, taking into account clinical and cost consequences, and supports resource allocation decisions. After safety, efficacy, and effectiveness, cost-effectiveness has been recognized as the major “fourth hurdle” to secure market access in many developed countries around the world. Health economics is successfully used to support decision making in medical device use, in-vitro diagnostics, and medical procedure areas.
While having a long history of use in the United States, Europe, Canada, Australia, and other countries, health economics has only recently emerged as a decision-making supportive tool in Asian countries. The People’s Republic of China, with a population of >1.3 billion people and with a growing economy, is an attractive market for manufacturers of medical devices and pharmaceuticals. The People’s Republic of China’s medical device market has become the world’s second largest in 2010, with a market size having exceeded 15.8 billion US dollars (USD). However, reimbursement for medical devices is limited and complex, especially for innovative products. With the growing role of health economic evaluations, it is important to evaluate the status of this area in the People’s Republic of China in terms of quantitative data, characteristics, and methodological approaches for evaluations of devices.

There is a lack of information concerning how the People’s Republic of China performs as a stakeholder in terms of health economic evaluations revolving around medical devices and whether or not, or how cost-effectiveness is addressed in the Chinese health care setting. Therefore, the objective of this study was to review the methodological quality of health economic evaluations of medical devices performed in the People’s Republic of China.

Methods

Literature search and citation screening

A systematic literature search was performed in the following databases: Medline, Medline In-Process, the National Health Service Economic Evaluation Database (NHS EED), and the Cost-Effectiveness Analysis (CEA) Registry of the Tufts Medical Center, as well as the Wanfang Database for studies published in Chinese. The Wanfang Database is an affiliate of the Chinese Ministry of Science and Technology and provides access to a wide range of data, including medical and scientific areas. The full-search strategy for each specific database is presented in the Supplementary materials. The searches were conducted on February 20, 2013 for Medline, on February 25, 2013 for the NHS EED and the CEA Registry, and on March 1, 2013 for the Wanfang database. The search spanned the period from January 1, 1990 to January 31, 2013.

Screening of abstracts and evaluations of full-text publications was performed by a single reviewer using the inclusion/exclusion criteria provided below. A second reviewer checked the appropriateness of inclusion of studies. Disagreements were resolved by consensus.

Study selection

The following inclusion criteria were used:
1. Type of studies: CEA, cost–utility (CUA), cost–benefit (CBA), cost-minimization (CMA), cost–consequences (CCA), and budget impact analyses. Economic evaluations as a part of published health technology assessments were also considered.
2. Type of interventions: Medical devices, in-vitro diagnostics, and procedures using medical devices were considered.
3. Language: Publications in English or Chinese were included.
4. Type of publication: Full-text publications in peer-reviewed journals and abstracts of conference proceedings were included.
5. Setting: The study should have been conducted in a Chinese setting.

Data extraction and analysis

Data from included publications were extracted by one reviewer and presented in the format outlined below. The following information was extracted: title, first author, payer perspective, population/settings, intervention, comparator, time horizon, type of economic evaluation, type of study (economic evaluation alongside clinical trial, modeling), type of analysis (CEA, CUA, etc), cost and cost categories (direct, indirect, etc), source of funding, results (incremental cost-effectiveness ratio [ICER] or total cost per intervention), main conclusion, and language of publication. A second reviewer assessed the quality of the data extraction.

Summary statistics were calculated. No formal statistical analysis was used due to the descriptive nature of this study.

Results

Literature search and citation screening

The literature search of electronic databases returned 3,043 initial hits. In total, 57 publications were included in the study. Detailed information about the search process is presented in Figure 1. A list of excluded publications with the reasons for exclusion is presented in the Supplementary materials.
Description of identified studies

Fifty-seven studies in total were available, 26 (46%) of which were in English and 31 (54%) of which were in Chinese. Methodological characteristics of included publications are presented in Table 1.

Design and methodology of economic evaluations

Most of the studies (n=31, 54%) were cost analyses of routine care. Among the others (n=26, 46%), 13 (50%) used decision analytic modeling, whereas the other 13 were trial-based evaluations. Thirty-two studies (56%) adopted a hospital perspective, whereas five (9%) adopted a third-party payer perspective, while the remaining studies (n=20, 35%) were from a societal perspective.

Time horizon was reported in 36 (63%) articles. Most studies (n=25, 44%) used the respective study’s follow-up as the time horizon. There were 22 (39%) and three (5%) studies that used hospital stay and lifetime as time horizons, respectively.

Discounting was applied in 12 (21%) studies; four of these discounted future costs with 3% of the annual rate, one discounted future costs with 5% of the annual rate, and seven discounted both future costs and benefits with 3% of the annual rate.

The source of funding was reported in 19 (33%) studies. Of these, three articles had funding from academia, ten studies had funding by the government, three articles had funding by both government and academia, one study had personal support, and two studies specified that there was
Table 1: Methodological characteristics of publications included in the analysis

| Author, reference | Type of intervention | Type of evaluation | Type of analysis | Perspective | Time horizon | Cost categories | Year of costing | Discounting | Economic outcomes | Sensitivity analysis | Source of funding |
|-------------------|----------------------|--------------------|------------------|-------------|--------------|----------------|----------------|-------------|-------------------|-------------------|------------------|
| Wang and Huang14  | Imaging              | M                  | CEA, CUA         | H           | –            | DM             | 2010           | C-5%        | ICER, total cost | One-way           | A                |
| Zhang and Yang15  | Screening            | TBE                | CCA              | HCP         | –            | DM             | –              | –           | Total cost          | –                 | –                |
| Wei et al16       | Surgery              | CA                 | CCA              | H           | Hospital stay | DM              | –              | NA’         | Total cost          | –                 | –                |
| Kim et al17       | Screening            | M                  | CLIA             | S           | Lifetime     | DM, DNM, I     | 1999/2000      | CB-3%       | ICER, total cost   | –                 | –                |
| Woo et al18       | Screening            | M                  | CEA, CUA         | S           | Study follow-up | DM, DNM, I   | –              | CB-3%       | ICER, total cost   | –                 | –                |
| Wong et al19      | Screening            | M                  | CEA, CUA         | S           | Study follow-up | DM              | 2005         | CB-3%       | ICER, lifetime costs | –                 | –                |
| Wong et al20      | Screening            | M                  | CEA, CUA         | S           | Study follow-up | DM, DNM        | 2005         | CB-3%       | ICER, lifetime costs | Prob             | G                |
| Gong et al24      | Surgery              | TBE                | CCA              | H           | Study follow-up, hospital stay | DM             | –            | Total cost | –                 | –                 | –                |
| Feng et al25      | Surgery              | TBE                | CCA              | S           | Study follow-up, hospital stay | DM, I          | –            | Total cost | –                 | –                 | G                |
| Chen et al26      | Cardiac surgery     | CA                 | CCA              | H           | Study follow-up, hospital stay | DM             | –            | Total cost | –                 | –                 | –                |
| Zang et al27      | Surgery              | CA                 | CCA              | H           | –            | DM             | –              | –           | Total cost          | –                 | –                |
| Gurbanov et al28  | Life support         | CA                 | CCA              | H           | –            | DM, DNM        | –              | –           | Total cost          | –                 | –                |
| Zhang et al29     | Kidney intervention  | TBE                | CCA              | H           | Hospital stay | DM             | –              | NA’         | Total cost          | –                 | N                |
| Liu et al30       | Imaging              | TBE                | CCA              | H           | Study follow-up | DM, DNM        | –              | NA’         | Total cost          | –                 | –                |
| Xie et al31       | Bone surgery         | CA                 | CCA              | H           | Study follow-up | DM              | –            | Total cost | –                 | –                 | G, A             |
| Lu et al32        | Surgery              | CA                 | CCA              | H           | Study follow-up, hospital stay | DM, DNM       | –            | Total cost | –                 | –                 | –                |
| Yang et al33      | Screening            | M                  | CBA              | S           | Lifetime     | DM, I          | 2008          | CB-3%       | ICER, total cost   | One-way           | G                |
| Sheng et al34     | Surgery              | TBE                | CCA              | H           | Study follow-up, hospital stay | DM             | –            | Total cost | –                 | –                 | –                |
| Wang et al35      | Screening            | M                  | CEA              | S           | Study follow-up, hospital stay | DM              | 2010         | CB-3%       | ICER, total cost   | One-way           | –                |
| Huang et al36     | Screening            | M                  | CEA, CUA         | S           | Lifetime     | DM, DNM, I     | 2009          | –           | ICER, total cost   | One-way           | –                |
| Wu et al37        | Surgery              | CA                 | CCA              | H           | Study follow-up, hospital stay | DM              | –            | Total cost | –                 | –                 | –                |
| Xia et al38       | Obstetrics           | CA                 | CCA, CMA        | H           | Study follow-up | DM              | –            | NA’         | Total cost          | –                 | –                |
| Chen et al39      | Kidney intervention  | TBE                | CUA              | S           | Study follow-up, hospital stay | DM, DNM, I     | 2003          | –           | ICUR, total cost    | One-way           | G                |
| Chen et al40      | Surgery              | CA                 | CCA              | S           | –            | DM, DNM, I     | –              | –           | Total cost          | –                 | –                |
| Author(s)         | Field                  | Methodology          | Cost Components | Year   | Discount Rate | Total Cost | One-Way Cost |
|-------------------|------------------------|----------------------|-----------------|--------|---------------|------------|--------------|
| Fan et al (2015)  | Imaging                | CA                   | CEA HCP         | –      | –             | DM         | –            |
| Gu et al (2015)   | Imaging                | M                    | CCA HCP         | –      | –             | DM         | –            |
| Fu et al (2015)   | Vascular surgery       | CA                   | CEA HCP         | –      | –             | DM 2007 C-3% | –            |
| Guan et al (2015) | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I 2002 | –            |
| Guo et al (2015)  | Screening              | M                    | CEA S           | –      | –             | DM         | –            |
| Han et al (2015)  | Respiratory support    | CA                   | CCA HCP         | –      | –             | DM         | –            |
| He et al (2015)   | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I 1999 | –            |
| Hou et al (2015)  | Imaging                | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Gen (2015)        | Kidney intervention    | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Guo (2015)        | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I 1999 | –            |
| Lan et al (2015)  | Respiratory support    | TBE                  | CCA HCP         | –      | –             | DM         | –            |
| Li and Liu (2015) | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I | –            |
| Liu et al (2015)  | Bone surgery           | TBE                  | CEA, CUA HCP    | –      | –             | DM, DNM    | –            |
| Ma et al (2015)   | Vascular surgery       | CA                   | CCA HCP         | –      | –             | DM 2010 NA | –            |
| Peng et al (2015) | Surgery                | M                    | CUA S           | –      | –             | DM, DNM    | –            |
| Tan et al (2015)  | Surgery                | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Tan (2015)        | Surgery                | CA                   | CCA S           | –      | –             | DM, I      | –            |
| Wang et al (2015) | Surgery                | CA                   | CEA HCP         | –      | –             | DM         | –            |
| Wang et al (2015) | Bone surgery           | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Wei et al (2015)  | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I | –            |
| Wen et al (2015)  | Kidney intervention    | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Xia (2015)        | Surgery                | CA                   | CCA S           | –      | –             | DM, DNM, I 2005 | C-3%        |
| Yu (2015)         | Surgery                | CA                   | CCA S           | –      | –             | DM         | –            |
| Zhou et al (2015) | Surgery                | CA                   | CCA HCP         | –      | –             | DM         | –            |
| Wu and Zen (2015) | Ophthalmology          | TBE                  | CCA HCP         | –      | –             | DM         | –            |
| Liu et al (2015)  | Surgery                | TBE                  | CCA HCP         | –      | –             | DM         | –            |
| Han et al (2015)  | Ophthalmology          | CA                   | CCA HCP         | –      | –             | DM, DNM    | –            |
| Liu et al (2015)  | Airway surgery         | TBE                  | CCA HCP         | –      | –             | DM         | –            |
| Lv et al (2015)   | Surgery                | CA                   | CCA HCP         | –      | –             | DM         | –            |

Note: NA, not applicable for studies with duration of <1 year.
Abbreviations: A, academia; CA, cost analysis of routine care; CCA, cost-consequence analysis; CEA, cost-effectiveness analysis; CMA, cost-minimization analysis; CUa, cost–utility analysis; C-%, cost discounted – annual discount rate; CB-%, cost and benefit discounted – annual discount rate; DM, direct medical cost; DNM, direct nonmedical cost; G, government; H, hospital; HCP, health care payer; I, indirect cost; ICER, incremental cost-effectiveness ratio; M, modeling; N, none; NA, not applicable; P, personal; Prob, probabilistic; QALY, quality-adjusted life year; S, society; TBE, trial-based evaluation; –, not reported; CBA, cost-benefit analysis.
no supporting funding. There was no single study reporting funding from the industry.

Among all studies involving a health economic analysis, 40 (69%) used a CCA; seven (12%) both a CCA and a CEA; five (9%), a CEA; three (5%), a CUA; one (2%), a CBA; and one (2%), both a CCA and a CMA.

Concerning studies in clinical areas, 23 (40%) involved surgery, nine (16%) involved screening, six (11%) involved imaging, four (7%) involved kidney intervention, three (6%) involved bone surgery, two each involved cardiac surgery/vascular surgery/respiratory support/ophthalmology (3% each), and one each involved oncology/life support/obstetrics/airway surgery (2% each).

Resource use and cost inputs
Among 44 nonmodeling studies, only 14 (32%) reported resources used and the quantity used for each resource. Thirty studies reported the source of unit cost, 16 (53%) of which adopted local unit costs from hospitals, ten (33%) used regional unit costs, one (3%) used national unit cost as a reference, and three (10%) used both local and regional sources. There was only one study (2%) with a regression analysis on cost available. All (n=57) studies reported direct medical costs. Direct nonmedical costs were reported in 19 (33%) studies, and indirect costs were reported in 14 (25%) studies.

Sensitivity analysis
Among the 13 studies that used modeling, eleven (85%) conducted sensitivity analyses; six (55%) of these had a one-way sensitivity analysis, one (9% of 11) conducted both one-way and two-way sensitivity analyses, and four (36% of 11) reported a probabilistic sensitivity analysis.

Among nonmodeling studies that conducted one-way sensitivity analyses, there were two (4%) that conducted trial-based evaluations and four (7%) that conducted cost analyses of routine care.

Outcomes of economic evaluations
The ICER was presented in ten (18%) studies, eight (80%) of which were screening studies, while the remaining two (20%) were studies in imaging and oncology areas. The reported ICER (with year of costing available) ranged from 12 USD per life-year saved (USD/LYS) for the single colonoscopy screening strategy to 6,014 USD/LYS for an additional positron emission tomography/computed tomography (CT) screening when compared with conventional CT staging.

Detailed information on population, settings, comparators, results, and conclusions is provided in the Supplementary materials.

Discussion
The present study is one of the first attempts to evaluate the status of health economic evaluations of medical devices in the People’s Republic of China. This study complements existing literature on methodological quality of the health economic evaluations in regions by raising the issue of application of this concept in decision making.71–73 While other systematic reviews are focused on health economic evaluations in general and mainly include evaluations of pharmaceuticals, our review is aimed on research in medical device and in-vitro diagnostic areas. Specifics of economic evaluation of medical devices in comparison with pharmaceuticals have been extensively reviewed elsewhere.74 This includes difficulties in conducting randomized controlled trials, “learning curve” and usability aspects, wider organizational implications, a shorter life cycle, fast price erosion, etc. Moreover, reimbursement and funding for medical devices differ significantly than for pharmaceuticals, as a special approach is required for the evaluation of medical device studies.

This study reveals that literature on health economics of medical devices in the People’s Republic of China is limited (57 publications in total from the year 1990), and the majority of the publications (53%) include cost or CCAs of routine care. Decision analytic modeling and within-trial evaluations have been used equally.

To include the majority of relevant studies, the search was also conducted using a local Chinese bibliographic database. Although locally published studies bring value in terms of having a complete picture of available research, they may have different methodological quality. Interestingly, the majority of the studies published in Chinese (24 out of 31) used CCAs, mainly at the hospital level. On the other hand, nine out of the ten studies that reported ICER and nine out of 17 studies that conducted sensitivity analyses were published in English, while all the Chinese studies with sensitivity analyses conducted only one-way sensitivity analysis. Among the 13 studies that applied modeling approaches, ten studies were published in English. In addition, among 42 studies with study follow-ups longer than 1 year, only 13 had discounting available. Among these 13 studies, nine were published in English. This may reflect both interests from authors to increase exposure to international literature and to have the influence of international recommendations on good reporting.
practice on content of published articles. The development of clear guidelines for economic evaluations is clearly considered part of the strategy to increase application of these studies in decision making. Recently, Consolidated Health Economic Evaluation Reporting Standards were issued by the International Society for Pharmacoeconomics and Outcomes Research Task Force, which may help improve the quality of reporting of economic evaluations.

A sensitivity analysis was also conducted to account for the time that passed after the primary analysis was completed (January 2013 to December 2014). The analysis was performed using Medline and Medline In-Process on January 15, 2015, with the same search strategy that was used during the primary analysis. Among the 181 hits generated from the search, eight studies were identified. Most of the studies (n=4, 50%) were trial-based evaluations, and the remainder were cost analyses of routine care (n=2, 25%) and decision analytic modeling (n=2, 25%). Discounting was not applied in any article (it was not applicable to one study). Apart from one study published in Chinese, the remaining studies were published in English. Six studies (75%) used CCA, and both CEA and CUA were used in two studies (25%). In the two studies that used modeling, both conducted sensitivity analyses – one study conducted only one-way sensitivity analyses, while the other performed one-way, two-way, and probabilistic sensitivity analyses. However, it is worth mentioning that the study that conducted a CEA and CUA with decision analytic modeling and sensitivity analyses (one-way, two-way, and probabilistic) was conducted in the setting of Hong Kong, which runs a different health care system and medical device funding system than Mainland China. With these results, it appears that over the extent of the latest time period specified, the quality of the health economic studies performed in the People’s Republic of China remains the same.

This systematic review reveals several areas in which improvements in methodology and reporting are possible for Chinese health economic studies. These include reporting of resource used, sensitivity analysis, presentation of study’s results with ICER, both internal and external validation of decision analytic models, transparency on source of funding, etc.

The limited role of economic evaluations in reimbursement for medical devices in the People’s Republic of China should be taken into account while interpreting the findings of our study. On the national level, the health care system was financed through out-of-pocket payments (35%), social insurance schemes (35%), and government subsidies (30%). However, tier III hospitals (highest tier with highly specialized services) dominated 70% of the medical device market among the top 12 cities (including Shanghai, Beijing, and Guangzhou). They have a different purchasing pattern due to a different source of revenue than tier II hospitals. Tier III hospitals are expected to generate at least 40% of their revenue from out-of-pocket payments, while tier II hospitals have 20% of revenue coming from out-of-pocket payments. This also drives tier III hospitals to procure the most advanced products to boost demand for high-end medical devices, as well as to attract complex disease treatment to enhance out-of-pocket revenue. Thus, with a demand for top medical products, the scarcity of health economic evaluations in the People’s Republic of China needs to change, to determine which of these, eg, are cost-effective so that the rural areas could also consider which of these products may be accessible for them. Fee-for-service remains the main and basic payment mechanism. In most cases, reimbursement does not cover the cost of medical devices completely and there is no established mechanism for evaluating the long-term benefits and cost-effectiveness of technologies. If the role of reimbursement from public sources grows in future, it may lead to increased demand for clinical and economic evidence of benefits of medical technologies.

Conclusion
This study indicates that there are a limited number of economic evaluations of medical devices existing in the People’s Republic of China, and these are mainly focused on cost analysis and have methodological deficiencies. Further efforts are required from different stakeholders, including academia, state institutions, and the private industry, to improve health economic research capacity and to put the results of analyses into practice to ensure that decisions in health care are based on the best available clinical and economic evidence.

Disclosure
The authors report no conflicts of interest in this work.
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