Decision Tool of Medical Endoscope Maintenance Service in Chinese Hospitals: A Conjoint Analysis

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Abstract

Background: Quality and cost of medical device maintenance are dominant factors influencing hospitals' decision in choosing medical endoscope products. Effective and efficient medical device maintenance are also paramount for providing cost-effective and high quality of medical care. This research aims to facilitate decision-making at hospitals in choosing the suitable endoscope device and the associated maintenance service; it also aims to facilitate decision-making at suppliers to develop the right products and services to fulfill customer demands.

Methods: A cross-sectional survey was undertaken in 50 Chinese hospitals, including primary and tertiary hospitals. Moreover, 65 medical staff and 56 medical engineers were recruited from 50 Chinese hospitals. A comprehensive set of attributes were defined and investigated. Conjoint analysis and orthogonal design were used for survey design and statistical analysis.

Results: Attribute importance and utility values of decision-making factors were analyzed at the aggregate, occupation, and medical institution levels. (1) At the aggregate level, the most critical factor is "maintenance response" and the least

important one is "maintenance efficiency". (2) At the occupation level, medical staff paid more attention to "maintenance response" and medical engineers paid more attention to "maintenance quality". (3) At the medical institution level, Primary hospitals paid more attention to "maintenance price", while tertiary hospitals paid more attention to "maintenance quality".

Conclusions: In general, this study provides a more scientific decision-making tool to both hospitals in choosing maintenance service of medical equipment such as endoscopy, and it also helps manufacturers and suppliers improve the after-sales service.

Background

Maintenance service of medical equipment is crucial to ensure that a device operates in accordance with manufacturer specifications and aids diagnosis and treatment of medical conditions [1]. The actual costs associated with medical devices include purchase, maintenance, and reprocessing costs [2, 3]. The maintenance of medical device is also important for reducing the overall dispatch costs, ensuring timely patient treatment, and reducing mortality and risks during patients care [4].

As a medical device, the endoscopes must go through risk assessment which is an ongoing responsibility and must be managed as a top priority by manufacturers, suppliers (agents selling endoscopes), and hospitals. The maintenance service provided by manufacturers or suppliers is regarded as essential service and support for endoscopes such as Repairing, Pre-Maintaining, and Quality-Control. Good maintenance of medical devices must be implemented by hospitals to minimise device breakdowns or failures [5], and to make sure they are accessible and reliable when needed [6]. This is even more critical

for developing countries, such as China, who have much lower health expenditure per capita compared with developed countries [7].

The State Food and Drug Administration has introduced some national and industrial standards to audit the quality of medical endoscope products [8, 9]. Arab-Zozani et al. (2021) [5] also developed assessment checklists for medical device maintenance management, from the aspects of resources, service, education, quality control, inspection and preventative maintenance, information bank and management. However, the checklist was proposed using Iranian experience, and it may not be applicable to other countries. Nor has the checklist been tested in a real hospital context, hence the validity, reliability, and feasibility of the checklist require further examination. Furthermore, the factors included in the checklist are rather generic, and they do not specify attributes associated with inspection and maintenance service, such as response time, cost of inspection or repairing, etc.

To improve the service quality of medical endoscopes, several industry associations in China have explored various evaluation methods and conducted multiple demand surveys on the maintenance service of medical endoscopes. For example, Shanghai medical equipment quality control center conducted service evaluation and demand analysis of medical endoscopes as early as 2011 [10-12]. Assessment of service quality requires information concerning service to produce aggregate assessment scores or metrics. The ranking method proves to be a popular assessment method used to evaluate the quality of service to medical devices. Information relevant to service attributes is usually collected from systematic literature review or surveys [5].

To evaluate the quality of maintenance service provided to medical endoscopes, we need to develop a method that considers a comprehensive list of the attributes associated with medical endoscopes and determines the most effective or essential combination of attributes [13-15].

This research collected information concerning the maintenance service provided to medical endoscopes, through an experimental design and a conjoint survey. The survey was conducted with a representative sample of medical staff and medical device engineers across a subset of Chinese hospitals. The questionnaire was distributed via emails and social media platforms. Using conjoint analysis, we analyzed specific needs on endoscope's maintenance service by comparing rankings between medical staff and medical device engineers and between tertiary hospitals and primary hospitals. In the hospital context, we further explored the factors influencing the decision-making by purchasers, end-users, and maintenance managers when choosing endoscope products and services. The research will facilitate decision-making at hospitals in choosing the suitable endoscope device and the associated maintenance service; it also offers a framework to set up standards on maintenance service. Ultimately, it promotes the development of an economic and technological ecological environment in the endoscopy industry [16,17].

Methods

Respondents

To reduce the impacts of selection bias, the sampling method used in choosing respondents was random, and the professionals who met the criteria had an equal probability of being enrolled through a non-probabilistic, convenience sampling method.

We conducted the conjoint survey across 50 hospitals in different provinces in China, including both primary and tertiary hospitals.

The selection criteria of participants are: 1) participants worked in hospitals that purchased and used medical endoscopes in the last five years; 2) medical staff and medical engineers who had more than three years of experience in using or managing endoscopes. This study constitutes a part of one major research project sponsored by the Ministry of Science and Technology of China, running from 2017-19. Over the three years, recruitment of the participants for the project was achieved from multiple sources, including targeted emails and messages sent via social media platforms (such as Wechat). In the end, 50 Chinese hospitals signed an agreement to participate in the primary research project and this study.

Experimental method

Experimental design refers to the process of generating specific combinations of attributes (factors) and levels evaluated by respondents. In this study, conjoint analysis and orthogonal design were used for experimental design and statistical analysis. Conjoint analysis is a survey-based statistical technique used to help determine how people evaluate different attributes of products or services, such as functions and features [25]. The conjoint analysis presents choice alternatives between products or services defined by a combination of attributes; it can also be used to determine each attribute's relative importance and which levels of each attribute are most preferred. In conjoint analysis, each profile describes a complete product or service, and it is defined by a different combination of factor levels for all factors of interest. The full-profile approach is used in conjoint analysis, where respondents score, rank, or order a set of profiles. If the number of combinations of factor levels is too large, a fractional factorial design is introduced to deal with the problem. A fractional factorial design, also called orthogonal design, selects a fraction of all possible combinations of factor levels to capture the main effects for each factor level. The Orthogonal design is typically a starting point of a conjoint analysis [26, 27]. The rest of the combinations that are not used in the orthogonal design are called holdout profiles.

In an orthogonal design, we assume there are K factors, and each factor has n levels, i.e., $t_1, t_2, \dots, t_n$. If this design meets two conditions: different levels of each factor appear the same number of times in the test (equilibrium); different combinations of factor levels for any two factors appear the same number of times in the test (orthogonality), this design is called orthogonal design. The orthogonal design is used to generate an orthogonal array, which can make the distribution of test points very uniform and reduce the number of tests. In this study, an orthogonal array is used to generate factor-level combinations of profiles, also called cards, which are rated by the respondents (also called subjects).

A random sample of subjects (respondents) from the target population is selected to evaluate the set of profiles or cards. The subjects assign a preference score to each profile based on intuitive experience. The

reference score can be a Likert scale or a number between 1 to 100. Alternatively, subjects can assign a rank to each profile using a number from 1 to the total number of profiles.

The survey data results are analyzed in a utility score, called part-worth, which provides a quantitative measure of preference for each factor level. Each factor or attribute has multiple levels; we are interested in each attribute's preference value or relative importance. The calculation of attribute importance value is presented in a multivariate framework [28, 29]:

$$Z(x)=e_{ij}+\sum_{i=1}^k \sum_{j=1}^n U_{ij} * X_{ij} \quad (1)$$

Where $Z(x)$ is the overall utility for a card (profile), rated by the subjects; U_{ij} represents the part-worth utilities for factor level j of factor i ; X_{ij} represents the level of a factor (attribute); it is a categorical variable, measuring whether factor i at level j is absent ($=0$) or present ($=1$) in this card (profile). K is the number of factors; n is the number of levels in each factor. U_{ij} is the value of interest, and it is estimated using Ordinal Least Square method using the linear regression model. And e_{ij} is the stochastic error term.

Once utility score U_{ij} is obtained, the range of the utility score for a factor i is calculated as the difference between the maximum and the minimum part worth utility:

$$\text{Range of Utility Score of factor } i = \max (U_{ij}) - \min (U_{ij}) \quad (2)$$

The importance value of factor (attribute) i is expressed as:

$$\frac{\text{Range of Utility Score of factor } i}{\sum_{i=1}^K \text{Range of Utility Score of factor } i} \quad (3)$$

The factor (attribute) importance value ranges between 0 and 1. The greater the value, the more important of the factor in the evaluation system of endoscope maintenance service.

In this study, the combinations of different factors and related levels of medical endoscopes were created based on the results from the Delphi method [30]. The set of profiles (cards) were created through orthogonal experimental design, which required the subjects (respondents) to assign preference to each combination intuitively based on experience; then, the importance of each factor and the effect of factor level are calculated using equations (1)-(3).

Research process

Cross-sectional survey

Since little was known about preferences for different attributes of endoscope maintenance, a cross-sectional survey was adopted to obtain a snapshot of the participants' views on the endoscope maintenance service. A cross-sectional survey was conducted in 2019 to assess the participants'

preferences on endoscopes' maintenance service. The advantages of cross-sectional surveys are fast and cost-effective. However, this is a one-off measurement over a short period; it is challenging to derive causal relationships among factors based on the cross-sectional survey results.

Conjoint analysis and Orthogonal experiment design

To inform questionnaire design, we selected combinations of different factors and related levels of the medical endoscope from the factors reported in which used two rounds of the Delphi method to assess the service level of endoscopes [30]. A straight set of factors and levels of factors were identified from the Delphi method for medical endoscope maintenance service, including maintenance quality, maintenance price, maintenance response, maintenance efficiency, and service provider. Each factor contains multiple levels, and the meaning of each factor and level is shown in Table 3.

For example, there were three levels of maintenance quality, defined as “the same fault happened within 6 months”, or “the same fault happened between 6 months and 12 months”, or “the same fault happened after 12 months. Maintenance price varied with the hard endoscope and soft endoscope, as defined at the three levels. Similarly, maintenance response rate and efficiency were also measured at three levels. Service provision was classified as the service provided by the original manufacturer or by the third-party service agents.

The questionnaire contains three sections (see Table S1 in the Supplementary Information): (a) demographic information of the respondents, including employer information, occupation, number of years of working, Etc.; (b) an explanation of the maintenance service attributes and levels, as well as the type of method used to assign preference scores; and (c) the main body of the questionnaire, presenting the combinations (also named as cards or profiles) of the factor levels. Each respondent was asked to answer the question of "how likely would you choose the above service?" using the ten-level Likert scale (score 1-10) [31].

The full-profile approach of Conjoint analysis generates 162 ($3 \times 3 \times 3 \times 3 \times 2$) profiles resulting from all possible combinations of the factor levels. The total number of 162 became too big for respondents (subjects) to rank or score in a meaningful way. So, the orthogonal design was used to reduce the number of combinations and retain the main effects of combinations that reflect the service attributes of medical endoscopes. The orthogonal experimental design was carried out in SPSS software, and a reduced set of 16 profiles (cards) were generated. The 16 cards represented different combinations of factor levels of the medical endoscope, and the sample card is shown in Figure 1. The number of 16 profiles was small enough to include in a survey but big enough to assess the relative importance of each factor [32].

Selection and information bias

The experimental study design means that selection bias and information bias might exist, which is the limitation of this research. Selection bias could result from selecting the respondents (subjects) in the conjoint analysis, limiting the comparability between groups (medical staff and medical engineers;

primary and tertiary hospitals) being studied. To reduce the impacts of selection bias, the sampling method used in choosing respondents was random, and the professionals who met the criteria had an equal probability of being included in the study. Future work will expand the conjoint analysis to include more subjects and refine the conjoint analysis results further.

A questionnaire helps collect perspectives, views, and opinions on the preferences of endoscope service attributes. However, information bias may arise from self-reporting bias (recall bias) or inaccurate estimation. To overcome recall bias, we defined the selection criteria to choose respondents (subjects) to participate in the questionnaire, requiring more than 3 years of experience in using or managing medical endoscopes. Therefore, these respondents were supposed to have up-to-date knowledge to evaluate the service attributes. To ensure the internal validity of the collected responses and minimize the impacts of inaccurate estimation, Pearson's correlation coefficient and Kendall's tau were calculated to check the reliability and validity of the regression model and estimated utility values.

The next phase of the study will involve surveys with a broader group of respondents who will rate the service attributes. In addition to using statistical methods, we will compare the survey data and the results from conjoint analysis with users' Evaluation reports or Technical reports on medical endoscopes to examine the validity and reliability of the self-reporting instrument.

Results

A total of 125 questionnaires were sent out, and 121 were recovered, of which 121 were valid, with an effective response rate of 96.8%. The group of 121 respondents consists of 65 medical staff and 56 medical engineers. Among the respondents, 27 were from the primary hospitals, and 94 were from tertiary hospitals. Table 1 shows the utility values and attribute importance scores of endoscope maintenance service rated by different respondents, i.e., medical staff, medical engineers, and the whole medical staff and medical engineers population. To verify the validity of the conjoint model, this study provided goodness-of-fit measures to determine if the hospitals behave according to their preferences. The internal validity of the conjoint analysis was worked out based on the correlations of the average rating score from the hold-out responses and the predicted levels of utility. In this study, the Pearson correlation coefficient was 0.875 ($p < 0.001$), and Kendall's tau was 0.662 ($p < 0.001$), indicating the conjoint model has a good fitting.

Table 2 shows the utility values and attribute importance scores of endoscope maintenance service rated by different hospitals, i.e., primary hospitals, tertiary hospitals, and the total hospitals.

Preferences of maintenance service of medical endoscope

According to the results of the conjoint analysis, the primary factor influencing medical staff and engineers' satisfaction with maintenance service is the "maintenance response" (23.665%), followed by "maintenance quality" (22.165%), "maintenance price" (20.961%), "service providers" (17.873%), and "maintenance efficiency" (15.336%), as shown in Table 1.

In Table 1, the utility values of the attribute level reflected the respondents' preference for the service selection. The greater the absolute value of the utility, the stronger the preference. The total population's preferences on endoscope maintenance services had the following features: for the attribute of "service provision", there was a big difference between the two levels. Compared with the other two attribute levels, the medical staff and engineers were more willing to accept the moderate level of maintenance quality, as the absolute value of this attribute level is the highest (3.690). The attribute "maintenance response" had three levels of positive utility values, of which the utility value of "3 days < maintenance response $\leq$ 7 days" received the highest score of 2.394. This result means that moderate maintenance response and receiving maintenance response within 7 days was most describable. The attribute of "maintenance efficiency" also had three levels of positive utility values, of which the factor level "10 days < maintenance time $\leq$ 20 days" received the highest utility value of 1.634, showing that this level of efficiency was most desirable for medical staff and engineers.

Analysis of preferences on service profiles

The results showed that medical staff and engineers tend to choose the service provided by the original manufacturer, with quick response time, short maintenance time, and low price. Compared with the other four attributes, a moderate level of maintenance quality (6 months the same fault $\leq$ 12 months) was generally acceptable to the medical staff and engineers. Medical endoscopes are operated in the human body with a high frequency of use, and the operating environment is complex. Therefore, there is usually a high failure rate, with an average maintenance frequency once per 12 months. The least favorable service profile was characterized by the *third-party service providers* and poor *maintenance quality* ("the same fault $\leq$ 6 months"), which was consistent with the actual expectations on endoscope maintenance service, i.e., there was strong resistance on the third-party maintenance service and poor maintenance service.

Analysis of preferences by respondents with different occupations

As shown in Table 1, the results showed no significant difference in attribute importance or factor utility values between medical staff and medical device engineers. The ranking of attribute importance was consistent between the two groups, showing that the selection preferences were identical in terms of *service provision*, *maintenance quality*, *maintenance price*, *maintenance response*, and *maintenance efficiency*. The utility values of factor levels varied between medical staff and engineers.

When choosing service provision, both groups preferred the service provided by the original manufacturer. However, medical engineers felt a slight difference between the maintenance service provided by the original manufacturer and the service provided by the third-party provider, while medical staff thought that the difference was significant.

Analysis of preferences by respondents from different medical institutions

As shown in Table 2, it was clear that *maintenance price* to primary hospitals matters more critically than *maintenance quality*, while quality matters more critically to tertiary hospitals. The different focus was related to the overall strength and performances of different medical institutions. Primary hospitals usually had less investment or resources assigned to medical device services. Hence, the maintenance quality was sacrificed as a trade-off to lower maintenance price. In contrast, tertiary hospitals' overall performances and capabilities were stronger to afford more expensive maintenance to ensure high maintenance quality. Although there was a difference in ranking attribute importance, primary and tertiary hospitals' most desirable maintenance service profile was identical.

Discussion

The influences of attributes on medical endoscope maintenance service

In evaluating maintenance service of medical endoscopes, medical staff and engineers put a stronger emphasis on two attributes, i.e., *maintenance quality* and *maintenance response*, and less attention was given to *service provision*, *maintenance price*, and *efficiency*. Users of medical endoscopes, represented by medical staff and engineers in this research, paid more attention to the maintenance quality of medical endoscopes and were not willing to accept the endoscope failure during use. Medical endoscopes are essential and commonly used medical devices in the medical examination process; when a malfunction occurs, the users expect prompt responses from the maintenance service providers to resolve the problem and maintain continuity in examination and treatment.

Since public hospitals benefit from partial financial subsidies from governments, they can afford high-quality (with relatively higher prices) medical endoscope maintenance services. They were not tolerant of low-price and low-quality maintenance services, nor were they interested in costly services [18].

Although *service provision* is a less important factor, the hospitals were resistant to *third-party service providers*. This result is attributed to the poor standards and the unreliable quality level of the third-party service [19, 20]. *Maintenance time* is the slightest concern. Medical endoscopes require high maintenance quality, which takes a relatively long maintenance time as a medical device. It took a long maintenance time to repair or maintain endoscopes, and this was generally accepted, especially when the service providers could offer alternative endoscopes to use.

Medical staff and engineers have different preferences on maintenance service

There was no significant difference between the medical staff and the medical engineer groups in ranking the five attributes. Medical staff and medical engineers put a strong emphasis on maintenance response, quality and price. Medical staff was lack of knowledge on the causes or mechanisms of endoscope failures; as endoscope users, they needed prompt response from service providers, thereby enhancing their understanding of the impacts of the failure on the diagnosis/treatment and giving them psychological support. Therefore, medical staff assigned higher preference scores to *maintenance response*. However, as providers of daily maintenance of medical endoscopes, medical engineers better

understood endoscopes' operation mechanism and working principles. When the medical endoscopes malfunctioned during use, they paid more attention to the causes of the malfunction, troubleshooting the problems and proposing solutions to fix the problems and avoid them in the future. With different emphasis and expectations on the maintenance service provision, medical engineers also assigned higher scores to maintenance response and maintenance quality.

Furthermore, in the event of a failure of endoscopes, medical engineers did not experience the same level of nervousness as medical staff, so they did not rate *maintenance response* as high as the medical staff. On the contrary, as users of endoscopes, medical staff did not understand the technical requirements of endoscope maintenance, so they had preference on the service provided by the original manufacturer. Compared with medical engineers, medical staff assigned a higher score (0.450) to the service provision by the original manufacturer.

Primary hospitals and tertiary hospitals had different preferences on maintenance service

By analyzing the attribute importance rated by respondents from different medical institutions, we found that *maintenance response* was the most critical factor for primary and tertiary hospitals. This result is due to the similar reasons discussed above, which led to medical staff and medical engineers assigning the highest score to this attribute.

Regarding the second most crucial attribute, tertiary hospitals emphasized *maintenance quality* while primary hospitals focused on *maintenance price*. It was related to the regional economic capacity, comprehensive strength of medical institutions, and operation mechanism of medical institutions. In recent years, private medical institutions in China have developed rapidly, and some hospitals have further expanded in groups and chains. This study observed that primary hospitals that rely on government funding were more cautious in terms of operating expenses [21]. This situation was reflected in the strong emphasis on *maintenance price*, higher than the score rated by tertiary public hospitals. As high-end medical equipment, medical endoscopes were widely used in higher-level medical institutions, but less used in low-level and private medical institutions was relatively low. Having a solid orientation towards low-price endoscope maintenance service puts the quality of maintenance at risk, leading to defective endoscopes used for diagnosis or examination. This situation is an important issue that is noteworthy and needs prompt action. According to the attributes of hospitals, hospitals can be divided into three different comparison groups: primary and tertiary hospitals, general and specialist hospitals, public and private hospitals. Primary hospitals and private hospitals are more sensitive to the price factor than tertiary and public hospitals. Considering the further opening of China's medical market and the vigorous development of private institutions, it can be predicted that demands on high-end and low-end medical products and services will continue to co-exist in China's medical market for a long time[22]. It is, therefore, imperative that medical product and service providers develop a comprehensive portfolio of products and services, to meet hospitals' diverse needs and specifications for functions, features, service, and price [23, 24].

Conclusion

In this study, the attributes and attribute importance that affect the maintenance service of medical endoscopes were obtained using conjoint analysis. A comprehensive analysis of preferences on service attributes was carried out at the aggregate, occupation, and medical institution levels. The research results provide a new decision making tool to hospitals to choose medical device and associated maintenance services; it also identifies the essential attributes and informs maintenance service development at medical device manufacturers or suppliers.

Despite the strengths in the Conjoint survey design and conduct, this study has several limitations. First, the eligibility criteria for choosing participants and hospitals may limit the generalisability of the findings. In addition, due to the online survey methodology and the nature of the convenience sampling method, our sample consisted of those with convenient access and those who were willing to share opinions on the maintenance service of endoscopes. Future work is needed to include moving various hospitals and participants to achieve the demographic, geographic, and socioeconomic diversity representatives of the endoscope users in China.

Second, research on preferences is limited in that the assigned preference weights are specific to the defined attributes and levels. In Conjoint analysis, it is possible that some essential attributes were not included, which may lead to inaccurate utility scores, as utility scores depend on the set of attributes and levels used to define a product or service.

Third, this study only describes the user preference of medical endoscopes, and it does not identify the factors that affect preferences and the causal relationships between them. Future work is needed to investigate such relationships.

Abbreviations

SPSS: Statistical Product and Service Solutions

Declarations

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Authors' contributions

JZ and J-YF have contributed to the study design and administration of the study. JL, L-GL, S-YC, and JS have contributed to the acquisition and processing of data. JZ drafted the manuscript. YX has reviewed the draft article and given specific comments. J-MW has contributed to data processing and performed statistical analysis. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

According to the "Ethical Review Measures for Biomedical Research Involving Humans" (2016) issued by order of the National Health and Family Planning Commission of the People's Republic of China (No.11), biomedical research involving humans includes the following activities: (1) research activities on human physiology, psychological behavior, pathological phenomena, disease etiology, and pathogenesis, and disease prevention, diagnosis, treatment, and rehabilitation; (2) testing and research activities of new medical technologies or new medical products on the human body; (3) the activity of collecting, recording, using, reporting, or storing scientific research materials such as human samples, medical records, and behaviors. This research is eligible for exemption from ethical review, and the need for consent to participate was waived by the Institutional Review Board, Research Management Department in the First Affiliated Hospital, Zhejiang University School of Medicine.

Consent for publication

Not applicable.

Competing Interests

The authors declare that they have no conflict of interest.

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Tables

Table 1 Utility scores and attributed importance rated by respondents with different occupations

Attribute	Level	Medical staff		Medical engineers		Population	
		Utility value	Attribute Importance (%)	Utility value	Attribute Importance (%)	Utility value	Attribute Importance (%)
Service provision	the original manufacturer	0.450		0.313		0.373	
			16.546		18.923		17.873
	1. By third party service providers	-0.450		-0.313		-0.373	
Maintenance quality	1. Same fault $\leq$ 6 months	-2.811	22.612	-2.601	21.811	-2.694	22.165
		-3.847		-3.565		-3.690	
	1. 6 months < the same fault $\leq$ 12 months						
	1. Same fault > 12 months	-3.106		-2.894		-2.988	
Maintenance price	1. Hard mirror $\leq$ 5000 yuan,	1.774	20.396	1.011	21.408	1.348	20.961
	soft mirror $\leq$ 10000 yuan						
	1. Hard mirror $\leq$ 10000 yuan,	2.469		1.416		1.881	
	soft mirror $\leq$ 30000 yuan						
	1. Hard mirror $\leq$ 20000 yuan,	2.087		1.215		1.600	
	soft mirror $\leq$ 50000 yuan						
Maintenance response	1. Response $\leq$ 1 day	1.547	24.328	1.519	23.141	1.531	23.665
		2.392		2.280		2.329	
	1. 1 day < response $\leq$ 3 days						
	1. 3 days < Response $\leq$ 7 days	2.533		2.284		2.394	
Maintenance efficiency	1. Maintenance time $\leq$ 10 days	1.226	16.118	1.071	14.717	1.140	15.336
		1.762		1.534		1.634	
	1. 10 days maintenance time $\leq$ 20 days						
	1. 20 days maintenance time $\leq$ 30 days	1.606		1.388		1.484	

Table 2 Preference scores rated by respondents from different medical institutions

Variable	Level	Primary hospital		Tertiary hospital		Population	
		Effect value	Weight %	Effect value	Weight %	Effect value	Weight %
Service provision	1. by the original manufacturer	0.350	16.378	0.380	18.307	0.373	17.873
	1. by third party service providers	-0.350		-0.380		-0.373	
Maintenance quality	1. Same fault $\leq$ 6 months	-2.639	20.399	-2.710	22.678	-2.694	22.165
	1. 6 months < the same fault $\leq$ 12 months	-3.579		-3.722		-3.690	
	1. Same fault > 12 months	-2.819		-3.036		-2.988	
Maintenance price	1. Hard mirror $\leq$ 5000 yuan, soft mirror $\leq$ 10000 yuan	1.620	21.479	1.269	20.811	1.348	20.961
	1. Hard mirror $\leq$ 10000 yuan, soft mirror $\leq$ 30000 yuan	2.181		1.794		1.881	
	1. Hard mirror $\leq$ 20000 yuan, soft mirror $\leq$ 50000 yuan	1.681		1.577		1.600	
Maintenance response	1. Response $\leq$ 1 day	1.250	26.946	1.613	22.713	1.531	23.665
	1. 1 day < response $\leq$ 3 days	1.958		2.437		2.329	
	1. 3 days < Response $\leq$ 7 days	2.125		2.472		2.394	
Maintenance efficiency	1. Maintenance time $\leq$ 10 days	0.880	14.799	1.215	15.492	1.140	15.336
	1. 10 days maintenance time $\leq$ 20 days	1.292		1.734		1.634	
	1. 20 days maintenance time $\leq$ 30 days	1.236		1.556		1.484	

Table 3 Endoscope maintenance service factors and levels

Service factors	Levels
Maintenance quality	1. Same fault $\leq$ 6 months
	1. 6 months < the same fault $\leq$ 12 months
	1. Same fault > 12 months
Maintenance price	1. Hard endoscope $\leq$ 5000 yuan, soft endoscope $\leq$ 10000 yuan
	1. Hard endoscope $\leq$ 10000 yuan, soft endoscope $\leq$ 30000 yuan
	1. Hard endoscope $\leq$ 20000 yuan, soft endoscope $\leq$ 500000 yuan
Maintenance response	1. Response $\leq$ 1 day
	1. 1 day $\leq$ Response $\leq$ 3 days
	1. 3 days $\leq$ Response $\leq$ 7 days
Maintenance efficiency	1. Maintenance $\leq$ 10 days
	1. 10 days maintenance $\leq$ 20 days
	1. 20 days maintenance $\leq$ 30 days
Service provision	1. Service provided by the original manufacturers
	1. Third-party service providers

Figures

Figure 1

A profile (card) of endoscope maintenance service

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1tableS1.Maintenanceservicepreferencequestionnaireofmedicalendoscope.pdf](#)