A Conjoint Analysis of Preferences on Medical Endoscope After-sales Service

Jun Zheng (✉ frankzheng@zju.edu.cn)

The First Affiliated Hospital, College of Medicine, Zhejiang University <https://orcid.org/0000-0003-0209-2060>

Jingming Wei

Peking University Institute of Mental Health

Ying Xie

Faculty of Business and Law, Anglia Ruskin University

Siyao Chen

Zhe first affiliated hospital, Zhejiang University school of Medicine

Jun Li

The First Affiliated Hospital, Zhejiang University of School of medicine

Ligang Lou

The First Affiliated Hospital, Zhejiang University School of Medicine

Jing Sun

The First Affiliated Hospital, Zhejiang University School of Medicine

Jingyi Feng

The First Affiliated Hospital, Zhejiang University School of Medicine

Research article

Keywords: Medical endoscope, After-sales service demands, Conjoint analysis

Posted Date: September 30th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-80985/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background: Medical endoscope instruments are minimally invasive, and they are widely used to investigate symptoms or help to perform certain types of surgery. This study investigates and defines a comprehensive set of attributes, to measure the after-sales service of medical endoscopes. The set of attributes help customers communicate their real needs with suppliers, and guide suppliers to develop the right products and services to fulfil customer demands.

Methods: Based on literature review and the findings from the Delphi study, we identified 5 factors (attributes) that best described the expectations on the after-sales service of medical endoscopes. Using conjoint analysis, a set of 16 combinations (also named as cards or profiles) of the factor levels were generated in orthogonal design and used to develop the questionnaire. We administered the cards to 65 medical staff and 56 medical engineers across 50 Chinese hospitals, asking them to assign a preference score to each card. The utility value of each factor level was estimated and attribute importance values were obtained.

Results: Attribute importance and utility values of factor levels were analysed at the aggregate level, occupation level, and medical institution level. (1) At the aggregate level, the five attributes were ranked in the order of importance values, the most important one is "maintenance response" and the least important is "maintenance efficiency". (2) Medical staff and medical engineers ranked the five attributes in the same order. However, 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 this study, the utility values and attribute importance that affected the after-sales service level of medical endoscopes were obtained using conjoint analysis. The research results were consistent with the actual market situation of medical endoscope service. In general, this study provides a more scientific solution for hospitals in choosing after-sales service of medical equipment, and it also helps manufacturers and suppliers improve the after-sales service.

Background

In medical endoscope market, service demand and product demand are two key factors influencing the choice of medical endoscopes. Medical endoscopes are important tools to perform minimally invasive clinical surgery and examination. Medical endoscopes are also commercial products that have the attributes of medical devices. As a medical device, 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 customer service provided by manufacturers or suppliers for endoscopes is not only an after-sales service for a commercial product, but also a high quality of service and support for safeguarding, repairing and maintaining endoscopes. The quality of customer service is an important factor affecting the hospitals' decision in purchasing medical endoscope products. The State Food and Drug Administration has introduced a number of national and industrial standards, to audit the

quality of medical endoscope products, however, the standards of evaluating the services provided to medical endoscopes do not exist [1–7]. In order to improve the service quality of medical endoscopes, several industry associations in China have explored various evaluation methods, and also conducted multiple demand surveys on the after-sales 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 year[8]. Ranking method is a popular method used to analyse the service quality of products. To make the ranking, questionnaire is distributed to collect the factors and information that influence ranking. Service Multiple factors, such as features, functions and benefits, make up a product or service. To evaluate the quality of after-sales 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 influential or important combination of attributes[9–12].

In this study, we used conjoint analysis to analyse and evaluate the after-sales service provided to medical endoscopes. Through a survey with 121 medical staff and engineers working in 50 hospitals in China, we analysed specific needs on endoscope's after-sales service, from the perspectives of medical staff, medical device engineers, 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 provides guidance to buyers in purchasing medical endoscopes; it also offers a framework to set up standards on after-sales service, and ultimately it promotes the development of an economic and technological ecological environment in endoscopy industry [13–16].

Respondents And Methods

Respondents

In this study, a random sampling method was used to select 50 hospitals in different provinces in China; these hospitals have purchased and used medical endoscopes in the last 5 years. The front-line medical staff and medical engineers who had experiences of using or managing endoscopes were appointed as subjects to rate a set of profiles (or cards) in the conjoint analysis. Each subject must have more than 3 years of working experience in using or managing medical endoscopes [17].

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. Conjoint analysis presents choice alternatives between products or services defined by a combination of attributes; it can also be used to determine both the relative importance of each attribute 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 [18–20]. 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., t1, t2, ..., tn. If this design meets two conditions: $\forall$ different levels of each factor appear the same number of times in the test (equilibrium); $\forall$ 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 not only make the distribution of test points very uniform, but also reduce the number of tests. In this study, 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.

Analysis of data from the survey results 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 the preference value or relative importance of each attribute. The calculation of attribute importance value is presented in a multivariate framework [21, 22]:

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

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. 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 after-sales service.

In this study, the combinations of different factors and related levels of medical endoscope were created based on the results from the Delphi method [23]. 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) [24].

Research process

Factors and levels of service preference of medical endoscope

An initial set of factors and levels of factors were chosen from literature review to define after-sales service of medical endoscope. This set of factors and levels were evaluated, filtered and revised by a group of experts through two rounds of Delphi method [23–26]. A refined set of factors and levels of factors were identified from the Delphi method for medical endoscope after-sales 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 1. 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 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.

Table 1
Endoscope after-sales service factors and levels

Service factors	Levels
Maintenance quality	1. Same fault $\leq$ 6 months
	2. 6 months < the same fault $\leq$ 12 months
	3. Same fault > 12 months
Maintenance price	1. Hard endoscope $\leq$ 5000 yuan, soft endoscope $\leq$ 10000 yuan
	2. Hard endoscope $\leq$ 10000 yuan, soft endoscope $\leq$ 30000 yuan
	3. Hard endoscope $\leq$ 20000 yuan, soft endoscope $\leq$ 500000 yuan
Maintenance response	1. Response $\leq$ 1 day
	2. 1 day $\leq$ Response $\leq$ 3 days
	3. 3 day $\leq$ Response $\leq$ 7 days
Maintenance efficiency	1. Maintenance $\leq$ 10 days
	2. 10 days $\leq$ maintenance $\leq$ 20 days
	3. 20 days $\leq$ maintenance $\leq$ 30 days
Service provision	1. Service provided by the original manufacturers
	2. Third party service providers

Orthogonal experiment design

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. To solve this problem, the orthogonal design was used to reduce the number of combinations, and to retain the main effects of combinations which 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 medical endoscope, and one of the cards was shown in Fig. 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[27].

Data collection

The questionnaire contained three sections: (a) demographic information of the respondents, including employer information, occupation, number of years of working, etc.; (b) an explanation of the after-sales 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 16 cards to each respondent and asking them to assign a

preference score to each card. 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).

In this study, medical staff who used endoscopes to perform diagnosis or treatment, and medical engineers who worked in hospitals and had responsibilities of maintaining and repairing endoscopes were invited to participate the survey. The respondents must have had over 3 years' working experiences, and 125 respondents from 50 Chinese hospitals were selected to evaluate medical endoscope after-sales services. 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%.

Results And Discussion

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. The Pearson correlation coefficient between the observed and estimated preferences (the observed and predicted rank orders for the holdout profiles) was 0.875 and the Kendall's tau was 0.662 ($p < 0.001$), showing the results were reliable and valid. Table 2 showed the utility values and attribute importance scores of endoscope after-sales service rated by different groups of respondents, i.e., medical staff, medical engineers and the whole population of both medical staff and medical engineers.

Table 2
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	1. by the original manufacturer	0.450	16.546	0.313	18.923	0.373	17.873
	2. 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
	2. 6 months < the same fault $\leq$ 12 months	-3.847		-3.565		-3.690	
	3. Same fault > 12 months	-3.106		-2.894		-2.988	
Maintenance price	1. Hard mirror $\leq$ 5000 yuan, soft mirror $\leq$ 10000 yuan	1.774	20.396	1.011	21.408	1.348	20.961
	2. Hard mirror $\leq$ 10000 yuan, soft mirror $\leq$ 30000 yuan	2.469		1.416		1.881	
	3. Hard mirror $\leq$ 20000 yuan, soft mirror $\leq$ 50000 yuan	2.087		1.215		1.600	
Maintenance response	1. Response $\leq$ 1 day	1.547	24.328	1.519	23.141	1.531	23.665
	2. 1 day < response $\leq$ 3 days	2.392		2.280		2.329	
	3. 3 days < Response $\leq$	2.533		2.284		2.394	

	7 days						
Maintenance efficiency	1. Maintenance time ≤ 10 days	1.226	16.118	1.071	14.717	1.140	15.336
	2. 10 days $\square$ maintenance time ≤ 20 days	1.762		1.534		1.634	
	3. 20 days $\square$ maintenance time ≤ 30 days	1.606		1.388		1.484	

Preferences of after-sale service of medical endoscope

Using equations (1)-(3), we obtained importance values of service attributes which reflected the hospitals' awareness of the importance ranking of service attributes. According to the results of the conjoint analysis, the major factor influencing medical staff and engineers' satisfaction on after-sales 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 2.

In Table 2, 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 whole population's preferences on endoscope after-sales services had the following features: for the attribute of "service provision", there was a big difference between the two factor levels. There was a stronger preference on the "service provided by the original manufacturer" which received a utility value of 0.373, while the "service provided by the third party" received a negative utility value of - 0.373. It seems that medical staff and engineers were reluctant to use the third-party service providers. Under the attribute of "maintenance quality", the utility values of the three factor levels were all negative, indicating that medical staff and engineers were not satisfied with the maintenance quality, regardless of the frequency of the same fault occurrence. Compared with the other two attribute levels, the medical staff and engineers were more willing to accept the moderate level of maintenance quality, i.e., 6 months $\leq$ same fault $\leq$ 12 months, as the absolute value of this attribute level is the highest (3.690). Regarding the attribute of "maintenance price", the utility values of the three factor levels were all positive, and the absolute values were relatively large, which showed that "maintenance price" was positively related to respondents' preferences, and the correlation intensity was relatively high. The preference on the price level of "hard mirror $\leq$ 10,000 yuan, soft mirror $\leq$ 30,000 yuan" received the highest utility value of 1.881, showing that hospitals preferred to receive better maintenance services at the expense of a higher price. 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 means that moderate maintenance response and receive 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

Using the orthogonal design, 16 endoscope after-sales service profiles defined by 16 combinations of the attribute levels were evaluated, and the attribute important scores were obtained. The optimal results were derived from the conjoint analysis: the most desirable endoscope after-sales service profile was: "6 months $\square$ the same fault $\leq$ 12 months", "hard mirror $\leq$ 5000 yuan, soft mirror $\leq$ 10000 yuan", "response $\leq$ 1 day", "maintenance time $\leq$ 10 days" and "service provided by the original factory"; while the least favorable service profile was: "the same fault $\leq$ 6 months", "hard mirror $\leq$ 20000 yuan, soft mirror $\leq$ 50000 yuan", "3 days < response $\leq$ 7 days", "maintenance $\leq$ 20 days" and "the third party provides services". The results showed that response time, maintenance time, maintenance price and service providers were important to medical staff and engineers, who 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 $\square$ the same fault $\leq$ 12 months) was generally acceptable to the medical staff and engineers. This was attributed to the following reasons: medical endoscopes are operated in human body with a high frequency of use, and the operating environment is complex, therefore, there is usually a high fault or failure rate, with an average maintenance frequency of 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 after-sales service, i.e., there was a strong resistance on the third-party post sales service and poor maintenance service.

Analysis of preferences by respondents with different occupations

Taking the occupation of respondents as a variable, we analysed and compared the relative importance of attributes, and factor utility values, rated by medical staff and medical engineers (see Table 2). The results showed that there was no significant difference existing in attribute importance or factor utility values between the two groups. 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, but medical engineers felt that there was a small 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 large. The different opinions were reflected in the utility values; 0.45 and - 0.45 were scored by medical staff, and 0.313 and - 0.313 were rated by engineers.

In terms of maintenance quality, both medical staff and engineers chose level 2, "6 months $\square$ the same fault $\leq$ 12 months", but the utility values of this factor level was different.

Doctors and medical engineers both chose maintenance price level 2, i.e., "hard mirror $\leq$ 10000 yuan, soft mirror $\leq$ 30000 yuan".

Both medical staff and engineers preferred the maintenance response level 3, i.e., "3 days < response $\leq$ 7 days", while medical engineers were also willing to accept level 2, i.e., "1 day < response $\leq$ 3 days". The scores assigned by medical engineers to levels 2 and 3 were 2.280 and 2.284, with a minor difference of 0.004. Medical staff rated levels 2 and 3 by 2.392 and 2.533, indicating that they were more inclined to accept level 3 rather than both levels 2 and 3. In addition, doctors and medical engineers were more willing to accept the maintenance efficiency level 2, i.e., "10 days $\leq$ maintenance $\leq$ 20 days". Both groups expected a high maintenance efficiency of endoscope after-sales service. The utility scores estimated from medical staff responses were higher than the utility values derived from engineers' responses, which to an extent reflect the professional characteristics of different occupations hospitals.

Analysis of preferences by respondents from different medical institutions

Taking the type of medical institutions as a variable, we analysed and compared attribute importance, and utility values of factor levels, rated by respondents from primary hospitals and tertiary hospitals (as shown in Table 3). The two types of hospitals ranked the attributes in different orders: primary hospitals ranked the attributes as 1) maintenance response (the most important), 2) maintenance price, 3) maintenance quality, 4) service provision and 5) maintenance efficiency (the least important); while the ranking assigned by tertiary hospitals is: 1) maintenance response (the most important), 2) maintenance quality, 3) maintenance price, 4) service provision and 5) maintenance efficiency (the least important). The weight ranking of different attributes and the selection of each attribute level are also consistent. It was clear that maintenance price matters more to primary hospital than maintenance quality; while quality was more important to tertiary hospitals. The different focus was related to the overall strength and performances of different medical institutions. Primary hospitals usually had less investment in, or resources assigned to medical device services, hence, the maintenance quality was sacrificed as a trade-off to lower maintenance price. While tertiary hospitals' overall performances and capabilities were stronger so that they could afford more expensive maintenance to ensure high maintenance quality. Although there was a difference in ranking attribute importance, the most desirable after-sales service profile chosen by primary hospitals and tertiary hospitals was identical, as defined by "service provided by the original factory", "6 months $\leq$ the same fault $\leq$ 12 months", "hard mirror $\leq$ 10000 yuan, soft mirror $\leq$ 30000 yuan", "response $\leq$ 7 days" and "7 days $\leq$ maintenance $\leq$ 20 days".

Table 3
Preference scores rated by response 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
	2. 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
	2. 6 months < the same fault $\leq$ 12 months	-3.579		-3.722		-3.690	
	3. 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
	2. Hard mirror $\leq$ 10000 yuan, soft mirror $\leq$ 30000 yuan	2.181		1.794		1.881	
	3. 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
	2. 1 day < response $\leq$ 3 days	1.958		2.437		2.329	
	3. 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
	2. 10 days < maintenance time $\leq$ 20 days	1.292		1.734		1.634	

3. 20 days □ maintenance time ≤ 30 days	1.236	1.556	1.484
---	-------	-------	-------

Discussions

The influences of attributes on medical endoscope after-sales service

In the process of evaluating after-sales service of medical endoscopes, medical staff and engineers put 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 was not willing to accept the endoscope failure during use. They preferred to high maintenance quality to ensure less device failure in a short period of time, which would cause less disruption to medical diagnosis and treatment. Medical endoscopes are important and commonly used medical devices in the medical examination process; when a malfunction occurs, the users expect prompt responses from the after-sales service providers to resolve the problem, and to maintain continuity in examination and treatment.

Since public hospitals are non-profit institutions and benefit from partial financial subsidies from governments, they had the advantages of being able to afford high quality (with relative higher prices) medical endoscope after-sales service. They were not tolerant with low-price and low-quality after-sales service, nor were they interested in excessively expensive services.

Regarding the service provision, although "service provision" is a less important factor, the hospitals were resistant to "third party service providers". This is attributed to the poor standards the third-party service and the unreliable quality level. From the market perspectives, there is an expectation that the third-party service providers to provide fast response, flexible, customised support at competitive price, hence become the primary after-sales service providers [28, 29]. "Maintenance time" is least concerned. As a medical device, medical endoscopes require high maintenance quality, which takes a relatively long maintenance time. 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 after-sales service

Hospital workers were divided into medical staff and medical engineers, and there was no significant difference in the five attribute importance values rated by medical staff group and medical engineers group. Medical staff and medical engineers put strong emphasis on maintenance response, quality and price. Since medical staff was lack of knowledge on the causes or mechanisms to endoscope failures, as endoscope users, they needed prompt response from service providers, thereby to enhance their

understanding of the impacts of the failure on the diagnosis/treatment, and to give them psychological support. Therefore, medical staff assigned higher preference scores to "maintenance response". However, as providers of daily maintenance of medical endoscopes, medical engineers had a better understanding of the operation mechanism and working principle of endoscopes. 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 it in the future. With different emphasis and expectations on the after-sales service provision, medical engineers also assigned higher scores to maintenance response and maintenance quality. Furthermore, in the event of there being a failure of a endoscopes, medical engineers did not experience the same level of nervousness as medical staff, so they did not rate "maintenance response" as high as medical staff. On the contrary, medical staff, as users of endoscopes, did not understand the technical requirements of endoscope maintenance, so they believed the service provided by the original manufacturer was the best. 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 after-sales service

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

With regards the second most important attribute, tertiary hospitals put more emphasis on "maintenance quality" while primary hospitals had more focus on "maintenance price". It was related to the regional economic capacity, comprehensive strength of medical institutions and operation mechanism of medical institutions. In China, most hospitals are non-profit public organizations that are primarily funded by governments and generate revenue through service charges and medicine charges. In recent years, private medical institutions in China have developed rapidly, and some hospitals have further expanded in the form of groups and chains. In this study, it was observed that primary hospitals that rely on full funding from governments were more cautious in terms of operating expenses. This was reflected in the strong emphasis on "maintenance price", which was higher than of the score rated by tertiary public hospitals. As a high-end medical equipment, medical endoscopes were widely used in higher level medical institutions, but less used in low-level medical institutions and private medical institutions was relatively low. Having a strong orientation towards low price endoscope maintenance service put the quality of maintenance at risk, which could lead to defective endoscopes used for diagnosis or examination. This is an important issue that is noteworthy and needs prompt actions. The segmentation of hospitals classified hospitals into different groups, for example, the primary and tertiary hospitals; general hospitals 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 [30-33]. It is, therefore, imperative that medical product and service providers develop a wide portfolio of products and services, to meet hospitals' diverse needs, and specifications for functions, features, service and price.

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 the selection of the respondents (subjects) in the conjoint analysis, which limits 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 equal probability to be included in the study. Future work will expand the conjoint analysis to include more subjects, and to further refine the conjoint analysis results.

The use of questionnaire is useful in collecting perspectives, views, and opinions on the preferences of endoscope service attributes. However, information bias may arise from self-reporting bias (such as recall bias), or inaccurate estimation. To overcome recall bias, we defined the selection criteria to choose respondents (subjects) to participate the questionnaire, requiring them having more than 3 years of experiences of using or managing medical endoscopes, therefore, these respondents were supposed to have up to date knowledge to evaluate the service attributes. To ensure internal validity of the collected responses and to minimise 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 study will involve surveys with a wider group of respondents who will rate the service attributes. In addition to the use of 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.

Conclusions

This study obtains the important factors and weights that affect the after-sales service level of medical endoscopes by conjoint analysis method, and comprehensively analyzes the service demand of medical endoscopes from the overall level, personnel level and medical institution level. The results of the study provide a new perspective and approach for the purchase of service products and the improvement of service mode of service providers.

In this study, the attributes and attribute importance that affect the after-sales service of medical endoscopes were obtained using conjoint analysis. A comprehensive analysis of preferences on service attributes was carried out at the aggregate level, occupation level, and medical institution level. The research results provide a new perspective and approach in choosing after-sales service for medical equipment; it identifies the important attributes and helps medical device manufacturers or suppliers developing effective after-sales service.

Declarations

Competing Interests

The authors declare that they have no conflict of interest.

Authors' contributions

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

Acknowledgements

The authors would like to thank Prof Yi Shen from Department of Statistics, Medical College of Zhejiang University, for reviewing this paper.

Authors' detail

¹The First Affiliate Hospital, Zhejiang University School of Medicine, Hangzhou 310003, China. ²Peking University Institute of Mental Health, Beijing 100191, China. ³Faculty of Business and Law, Anglia Ruskin University, Chelmsford Bishop Hall Lane, Chelmsford, CM1 1SQ, UK.

Funding

This work was supported by 13th Five-Year National Key R&D Program Service System Evaluation Research of Medical Endoscope Equipment (No. 2017YFC0113505) and 13th Five-Year National Key R&D Program Application Demonstration of Domestic Innovative Medical Equipment Based on Medical Internet+ (No. 2017YFC0114107). In both cases, the funding body provided financial support for the conduct of the research, having no involvement in the analysis or in writing the article.

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 the 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.

References

1. General Administration of quality. supervision, inspection and Quarantine of the people's Republic of China: GB/T27922-2011 Evaluation system for after-sales service of commodity. Beijing: China Standard Press; 2012.
2. General Administration of quality. supervision, inspection and Quarantine of the people's Republic of China: YY/T1587-2018 Medical endoscope electronic endoscope. Beijing: China Standard Press; 2018.
3. Jing jin-hong: Study on application of medical service based on the concept of product design. PhD thesis, Chongqing University. (2013).
4. Xu, Zhe. fang Ting-ting, Su Wen-ping: Application of combinatorial analysis in the research of consumers' preference for product attributes. The Journal of Quantitative Technical Economics. 2004;21:138–45.
5. Darbord JC. Importance of cleaning for reprocessing endoscopes and thermolabile sterile medical devices: French use and regulations. J Hosp Infect. 2004;56:40–3.
6. Wang Li-jun, Bin L. Zhang li-fang: 2010 Customer Satisfaction Report of Medical Equipment After Service in Shanghai Area. Chinese Medical Equipment Journal. 2012;27:88–90.
7. Bin LI, Li-jun W. Zhang Li-fang: 2007 Shanghai Customer Satisfaction Report of Medical Equipment After-service. China Medical Devices. 2009;3:68–71.
8. Xu Zi-tian, Bin L. Wang Li-jun: Survey report on satisfaction of after sales service of mainstream endoscopic equipment manufacturers in Shanghai in 2011. Chinese Medical Equipment Journal. 2013;34:104–5.
9. Lu B, Zhang S. A conjoint approach to understanding online buyers' decisions towards online marketplaces. Journal of Theoretical Applied Electronic Commerce Research. 2020;15:69–83.
10. Liangping Hu. Regression analysis based on the variable transformation(£) -the conjoint analysis method of the data with preference scores. Sichuan Mental Health. 2019;3:209–15.
11. Steve R, Makkar A, Williamson T, Turner. Using conjoint analysis to develop a system to score research engagement actions by health decision makers. Health Research Policy Systems. 2015;13:22.
12. Van Deen WK, Nguyen D, Duran NE. Value redefined for inflammatory bowel disease patients: a choice-based conjoint analysis of patients' preferences. Qual Life Res. 2017;26:1–11.
13. Breunig MC, O'Connell, Timothy S. The Impact of Outdoor Pursuits on College Students' Perceived Sense of Community. Journal of Leisure Research. 2010;4:551–72.

14. Tashjian VC, Haass S, Lhee E. Examining Individuals' Decision Making Surrounding Bowel Preps for Colonoscopy: Insights From a Conjoint Analysis Survey. *The American Journal of Gastroenterology*. 2018;113:85–7.
15. Joo W, Almario, Christopher V. Evaluation of the effect of label attributes over the purchase intention of a cashew nut functional beverage using conjoint analysis. *ACR open rheumatology*. 2020;2:391–400.
16. Welmoed K, Deen D, Nguyen NE, Duran. Value redefined for inflammatory bowel disease patients: a choice-based conjoint analysis of patients' preferences. *Qual Life Res*. 2017;26:455–65.
17. Sofian SS, Rambely AS: Evaluation of students' perceptions on game based learning program using fuzzy set conjoint analysis. *THE 4TH INTERNATIONAL CONFERENCE ON MATHEMATICAL SCIENCES: Mathematical Sciences: Championing the Way in a Problem Based and Data Driven Society* **1830**, 050004 (2017).
18. Pelsmaecker SD, Schouteten J, Lagast S. Is taste the key driver for consumer preference? A conjoint analysis study. *Food Qual Prefer*. 2017;62:323–31.
19. Eggers F. Felix Eggers, Sascha Kraus: Entrepreneurial branding: measuring consumer preferences through choice-based conjoint analysis. *International Entrepreneurship Management Journal*. 2016;12:427–44.
20. Naoki Takano. A Conjoint Analysis of Demand for the Japanese Mobile Phone Market. *The Review of Socionetwork Strategies*. 2016;10:1–15.
21. Liew T, Brooks. A conjoint analysis of inpatient satisfaction ratings in Indonesia. *Health Policy Technology*. 2017;6:105–13.
22. Kamel Jedidi ZJ, Zhang. Augmenting Conjoint Analysis to Estimate Consumer Reservation Price. *Management science: Journal of the Institute of Management Sciences*. 2002;48:1350–68.
23. Zheng J, Lou L, Xie Y. Model construction of medical endoscope service evaluation system-based on the analysis of Delphi method. *BMC Health Services Research*. 2020;20:1–13.
24. Dalkey N, Helmer O. An experimental application of the Delphi method to the use of experts. *Manage Sci*. 1963;9:458–67(.
25. Yoon SH, Lee H, Kwon CY. Development of a survey form through Delphi study about adverse events associated with the miniscalpel needle, for application in prospective observational studies regarding safety of miniscalpel needles. *Medicine*. 2018;97:e12736.
26. Wang JM, Qi JW, Sun J. Investigation on Medical Equipment Configuration and Identification of Obstacles in Aftersales Service of Primary Medical Institutions in Zhejiang Province. *Chinese Medical Equipment Journal*. 2020;35:13–7.
27. Zhao Min. Research on College Students' work attribute preference based on combination analysis. *Journal of Beijing University of Aeronautics Astronautics (Social Sciences Edition)*. 2016;1:110–6.
28. Zhang J. Lu gang, Wan guofeng: Status of large-scale hospital equipment maintenance and discussion on cooperation model of third-party services. *Chinese Medical Equipment Journal*. 2011;3:55–7.

29. Hong Gang-xuan. Research on the strategic alliance of the third party medical equipment service industry in China. PhD thesis, Central South University, 2013.
30. Zhou fang. Qiu Xiao-li, Fang ding: Application and Evaluation of Domestically-Manufactured Rigid Endoscopes in Primary Hospitals. Chinese Medical Equipment Journal. 2016;31:86–8.
31. Zhu You-li: Annual report of private hospitals in China. (2013). Social Sciences Academic Press, Beijing (2013).
32. Wang Gao-ling. Ye Tian-yu: Analysis of the Development of Private Hospital Under the Background of New Medical Reform in China. Chinese Hospital Management. 2016;36:4–27 (.
33. Kun Z, Taishi Z, Xiaoli Q. Discussion on the Medical Equipment After-Sales Service Mode for. Primary Medical Institutions. 2015;30:130–47.

Figures

Figure 1

A profile (card) of endoscope after-sales service