ORIGINAL ARTICLE

Determination of service key performance indicators for emergency departments of teaching hospitals in Malaysia: A fuzzy delphi method

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ABSTRACT

Introduction: The most crucial step in forming a set of key performance indicators (KPI) for emergency department's (ED) staff is deciding the appropriate items for the KPI. This article demonstrates Fuzzy Delphi Method (FDM) as a scientific approach to consolidate consensus agreement within a panel of experts pertaining to each service related KPI item's appropriateness for ED. We aimed to develop framework of service key performance indicators for emergency departments of tertiary centres by using FDM.

Materials and Methods: The panel consists of ten experts from ED that was randomly chosen from list of specialists obtained from the National Specialist Registry for Emergency Medicine. A set of questionnaires that contains item constructs related to KPI based on structure, outcome and process was developed from initial literature search from Pubmed Central, Google Scholar, Cochrane Database and Public Library of Sciences. The construct then used for FDM session in second phase of the study. In FDM phase, the experts will rank each of the items created from nominal group technique (NGT) session by using Likert Scale ranged from 1 to 5 ("1" totally disagree and "5" extremely agree). FDM prerequisite must include threshold value (d) ≤0.2, expert consensus of >75% and average fuzzy numbers ("A" value) of >0.5.

Results: The initial item construct has produced 22 items proposed for the service KPI. Post FDM analysis for service KPI, 16 out of the 22 (72%) satisfied first prerequisite "d" value ≤0.2. For the second prerequisite, ten items (45%) from service KPI domain had expert consensus of more than 75%. For the third prerequisite, 16 out of the 22 (73%) fit the criteria of average fuzzy number ("A" value) of more than 0.5. In final model of FDM, 13 items (59%) were discarded and the remaining (n=9 items) that fulfilled all three pre-requisites were retained for the final draft for content validation process.

Conclusion: This study introduces that FDM can be used to obtain experts' opinion and consensus in order to achieve a decision. The experts' consensus on the suitability of the pre-selected items on the KPI set were obtained, hence it is now ready for further applicability in the clinical setting in ED.

KEYWORDS:
Performance; quality, emergency department; KPI; service

INTRODUCTION

Emergency department (ED) serves as a vital role for any health care set up in providing care for variety of cases ranging from most critically ill to non-critical cases for whole range of population. Providing quality service in ED will enhance patients' outcome and generate trust among public who utilises the service.[1,2] Setting up key performance indicators (KPIs) in ED is crucial to ensure service provision is being monitored objectively and can serve as benchmarking for its performance against other set up within the same locality or abroad. KPIs also provide valuable information for institutions to set goals, support action plans, monitor implementation results, and to report results of their achievement. KPIs allow hospital stakeholders to identify critical points and problems that can be solved with low-cost actions, both in time and resources.[3,4] KPIs for ED in any given locality may be different from one to another as the need and capacity of its function may differ. For example, KPI framework for an ED of a tertiary teaching centre will be different from those KPI in non-academic ED centre or district hospitals.[5-7] Having a wrong KPI set up creates burden to an organisation resulting in poor compliance and in worst scenario waste financial and other resources. Hence setting up appropriate KPIs for an ED is crucial and it requires robust and reliable methods.

Unfortunately, at present time there are no standardised and common KPIs framework set up for emergency medicine service provision in teaching hospitals in the country and yet robust KPIs set up is essential to improve quality of teaching and learning whilst at the same time ensuring safety of patient care and staff. Therefore, given the vital role as well as the perpetual and indispensable service provided by the ED in teaching hospitals, it is necessary to evaluate the service provision in this unique setting in accordance to acceptable standards and criteria. Hence an effort was taken to create a framework of KPIs for service activities by using Fuzzy Delphi Method (FDM).[8,9] FDM uses expert opinion and consensus in reaching final decision of KPI contents for further construct validation before its final use in ED. The study was approved by local ethics and review board for

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human research and involved experts in emergency medicine throughout the country.

MATERIALS AND METHODS

The study utilised the Fuzzy Delphi Method (FDM) in obtaining consensus from experts on service KPI parameters of teaching hospitals in Malaysia. The principal investigator acted as the main facilitator who provided experts with online Google Form questionnaires. The experts were considered as experiencing in ED employment of >5 years as clinical specialists and involved in the scholarly activities in the specialty of Emergency Medicine. Our general approach was to select participants who have knowledge of the outcome and outcome assessment and with clinical and academic experiences in EM. For this reason, we used a purposive sampling approach for the participants based on the lists of EM staff employed in teaching hospitals obtained from administrative offices of the institutions. Currently, there are three major teaching hospitals in the country that provide specialty training program in EM. The selection expert members should reflect the population that is intended to use the KPIs. The Google form was sent directly to the experts handphone via WhatsApp® and Telegram® messaging to ensure the form reached the intended experts. This was followed by phone calls and messaging confirmation carried out by the investigators.

OUTCOME MEASURE & ANALYSIS

The study involved two phases:

Phase 1 (Literature Analysis)

The principal investigator listed out all potential initial draft KPIs to be assessed by the chosen experts. The initial draft was based on literature review and evidence based obtained from sources such as The PubMed Central, Google Scholar and Cochrane Library and Public Library of Science. The initial item constructs consist of three domains namely "Structure", "Outcome" and "Process" (SPO). Structure describes the context in which clinical care are delivered, including hospital buildings, staff, financing, and equipment. Process denotes the transactions between patients and providers throughout the delivery of healthcare activities. Finally, outcomes refer to the effects of healthcare on the health status of patients such as morbidity and mortality.

Phase 2

The FDM was used to obtain expert consensus on the feasibility and ranking top priority KPI parameters obtained from literature search for final use in the EM department of teaching hospitals. A set of KPI parameter assessment form was created by using a five-point Likert scale. (Table I) The pre-requisites to reach expert consensus consists of three elements. The first prerequisite required each item in the domain achieves threshold value (d) ≤0.2. The second prerequisite requires each item within the construct must achieve expert consensus of more than 75%.[10,11] The third prerequisite was used to rank the items within the constructs by calculating the average fuzzy numbers ("A" value). Items were accepted if the "A" value is more than 0.5.[12] The number of Fuzzy scales must be selected in odd numbers such as 3, 5, 7 and 9. The higher the Fuzzy scale value indicates the data is obtained more accurately. The survey was distributed to the experts in Google Form format via WhatsApp or Telegram text messaging platform.

Fuzzy Delphi Method (FDM) implementation steps.

Step 1

Selection of experts:

In the selection of experts, good results can be obtained even with small panels of 10-15 homogenous individual.[13] The concept of experts in FDM comprises of any of the following criteria such as individual having vast working experience in the field, those who are known for extensive scholarly work in the field of study and being recognized by certified bodies for his/her expertise. In this study the investigator had chosen ten experts within the field of EM and currently serve as EM specialists of >5 years' experience in a teaching hospital in the country. All of respondents are registered with the National Specialist Registry (NSR), Malaysian Medical Council and actively served as members of specialty conjoint member of EM trainee programme.

Step 2

The next step involved the conversion steps of all linguistic variables into triangular fuzzy numbers. A Triangular Fuzzy Number represents the value of m1, m2, m3 and is symbolised like (m1, m2, m3). The m1 value indicates the minimum value, the m2 value indicates a reasonable value and the m3 indicates the maximum value. Figure 1 shows the values of m1, m2, m3 for the Triangular Fuzzy Number. The m values represent the percentage likelihood the experts agree that the KPI parameters are important. (i.e., for Likert Scale 3: m1=minimally 20% agree it is important; m2=reasonably average likely 40% of experts agree it is important; m3=at most 60% of expert will agree it is important).

Step 3

The following step is identifying the value of threshold 'd'. The threshold value is very important in the step of identifying the level of agreement among experts. To obtain expert agreement for each item, the threshold value must not exceed 0.2 (14). However, the mathematical experts in FDM have always considered three decimal point value for inclusion of item acceptance due to minute value of fuzzy numbers evaluation ranging from 0 to 0.99999.[15,16] Therefore, if the d value is ≤0.299, it means experts reach an agreement on the item, otherwise the second round should proceed to survey whether the item is needed or not.

To obtain the threshold value (d), is calculated based on the formula:

$$d(\bar{m},\bar{n}) = \sqrt{\frac{1}{3}\left[(m1-n1)^2 + (m2-n2)^2 + (m3-n3)^2\right]}$$

Step 4

The second requirement for the FDM involves the step of determining the experts' agreement whether it is ≥75% for each item. If the percentage of expert agreement is ≥75% agreement for each item, then the item is assumed to reach the expert agreement. The percentage of expert's agreement can be calculated by using the formula:

Table I: Level of agreements and Fuzzy scale (5 points)

Linguistic Variables	Likert Scale	Fuzzy Scale
Not appropriate at all	1	(0.0, 0.0, 0.2)
Minimally appropriate	2	(0.0, 0.2, 0.4)
Moderately appropriate	3	(0.2, 0.4, 0.6)
Very appropriate	4	(0.4, 0.6, 0.8)
Extremely appropriate	5	(0.6, 0.8, 1.0)

Table II: Initial item constructs based on literature analysis outcomes for service KPI parameters

DOMAIN/ITEMS	KPI ITEM DESCRIPTION (SERVICE STRUCTURE-SS)
SS-1	BLS/ACLS/ATLS/PALS certification for all medical doctors working in Emergency Department (KPI outcome 80% of all doctors per any one certification)
SS-2	Minimum nursing to bed ratio in red zone (KPI: target 1:2)
SS-3	Minimum doctors to bed ratio in red zone (KPI: target 1:3)
SS-4	Maximum duration ambulances downtime annually (KPI: twice breakdown per ambulance per year)
SS-5	Annual budget allocation for point of care test (KPI: adequate to fulfill all tests request)
SS-6	Amount of Personal Protective Equipment provided and supplied annually (KPI: adequate to fulfil the use requirement)
	KPI ITEM DESCRIPTION (SERVICE PROCESSES-SP)
SP-1	Door to time to be seen by doctors/nurses in Critical (Red) Zone (KPI: 0 minute)
SP-2	Door to time to be seen by doctors/nurses in Semi Critical (Yellow) Zone (KPI: maximum 30 minutes)
SP-3	Door to time to be seen by doctors/nurses in Non-Critical (Green) Zone (KPI: maximum 120 minutes)
SP-4	Door to CT scan for CVA patient (KPI: within 30 minutes of arrival)
SP-5	Door to needle for thrombolysis in CVA (KPI: within 90 minutes of arrival)
SP-6	Door to thrombolytics for AMI (KPI: within 30 minutes of arrival)
SP-7	Ambulance response time (KPI: 15 minutes from call received at dispatch centre for hospital based ambulance services)
SP-8	Number of working hours per week for medical officers (KPI: maximum 70 hours per week)
SP-9	Number of working hours per week for nurses (KPI: maximum 60 hours per week)
SP-10	Hand hygiene practice among staff (KPI: 100% compliance)
	KPI ITEM DESCRIPTION (SERVICE OUTCOME-SO)
SO-1	Percentage of success thrombolysis in AMI (KPI: 70% of all cases thrombolysed)
SO-2	Percentage of success thrombolysis in CVA (KPI: 70% of all cases thrombolysed)
SO-3	Staff happiness index (KPI: 80% of staff is satisfied working in the department at any time)
SO-4	Number of patient/public complaints (KPI: maximum 5 complaints annually)
SO-5	Incidence of needle prick injury in department (KPI: zero incidence annually)
SO-6	Incidence of nosocomial infection among staff (KPI: zero incidence)

$$\frac{\text{Numbers of Item d} \leq 0.2 \times 100\%}{\text{Total Items}}$$

Step 5

The third criteria for the FDM, the α-cut is ≥0.5, indicates the item will be accepted as it shows the consensus of experts to receive the item. The calculation and determination of fuzzy values is by using as the formula below:

$$A = (1/3)*(m1 + m2 + m3)$$

If the value of A is more than the value of α-cut=0.5, then the item will be accepted as it shows the consensus of the expert to receive the item (17).

Step 6

The step of ranking or sub phases for the item. The ranking steps is by selecting the item based on defuzzification value (Value 'A" as above) based on expert agreement where the highest value of the item is determined by the most important ranking in the model.

The data entry from the Likert Scale obtained was translated into Fuzzy number data and analysed using FDM program in Microsoft Excel software. This data analysis technique is known as the Fuzzy Delphi or FDM technique. The study was approved by the host institution in accord to Declaration of Helsinki on ethical principles regarding human experimentation developed for the medical community by the World Medical Association (WMA).

RESULTS

A total of 22 item constructs for KPI service were identified at end of literature search for all three domains (Structure, Outcome, and Process). (Table II) All the items within the domains had scored average Likert scoring of three to five, which was in the scale of moderately appropriate to extremely appropriate. These scores were converted into fuzzy numbers. Sixteen out of the 22 items satisfied first prerequisite of "d" value ≤0.2. For the second prerequisite, ten items (45%) from service KPI domain had expert consensus of >75%. For the third prerequisite, 16 out of the 22 items (73%) fit the criteria of average fuzzy number ("A" value) of >0.5. Thirteen items (59%) were discarded and the remaining (n=9; 41%) that fulfilled all three prerequisites were retained. Apart from discarding items based on these prerequisites, little modification of items in terms of the structure, position and

Tabel III: Summary of all three prerequisite post Fuzzy Delphi analysis findings for Service KPI domain

Domain/Items	Average Likert Score	Threshold Value d < 0.2	Percentage Of Expert Consensus	Average Of Fuzzy Numbers (A value)	Ranking	Verdict***
Service Structure (SS)						
SS-1	4.7	0.147	90	0.740	2	Retained
SS-2	4.0	0.360	80	0.613	4	Discarded
SS-3	3.9	0.343	30	0.587	5	Discarded
SS-4	3.2	0.267	60	0.447	6	Discarded
SS-5	4.4	0.147	100	0.680	3	Retained
SS-6	4.8	0.098	100	0.760	1	Retained
Service Process (SP)						
SP-1	4.3	0.257	70	0.660	4	Discarded
SP-2	4.3	0.196	80	0.640	5	Retained
SP-3	3.6	0.387	30	0.527	8	Discarded
SP-4	3.9	0.344	30	0.593	6	Discarded
SP-5	4.5	0.214	90	0.700	3	Retained
SP-6	4.9	0.055	100	0.780	1	Retained
SP-7	3.1	0.225	70	0.427	10	Discarded
SP-8	3.3	0.370	50	0.473	9	Discarded
SP-9	3.9	0.227	60	0.587	7	Discarded
SP-10	4.8	0.098	100	0.760	2	Retained
Service Outcome (SO)						
SO-1	3.1	0.220	70	0.420	5	Discarded
SO-2	3.2	0.208	70	0.440	4	Discarded
SO-3	3.8	0.313	50	0.567	3	Discarded
SO-4	1.9	0.213	70	0.207	6	Discarded
SO-5	4.4	0.251	90	0.687	1	Retained
SO-6	4.3	0.252	90	0.667	2	Retained

***Prerequisite for retaining items based on expert consensus:

i. Threshold value (d) ≤ 0.2 (3 decimal points is accepted)
ii. Percentage expert agreement > 75%
iii. Average fuzzy value ("A" value) > 0.5

All three must be satisfied to retain the items

wordings were one based on the comments by the experts. These were some minor changes, and it did not alter the objective and nature of the items. Column for comments was provided in the last section of the Google Form as open questions and statements. Most of the comments were on simplifications of sentence structure and text format such "bold and italics". The whole findings were summarized in Table III and Figure 2.

DISCUSSION

This study introduces that FDM can be used to obtain experts' opinion and consensus in order to achieve a decision. This method can be used as a tool to select suitable items or content validation process before subjecting it to construct validation process. More importantly, this method provides a better quantitative approach compared to usual group discussions or meetings that are in a qualitative manner.[18,19] In addition, FDM approach does not require experts to meet physically and discuss topic of interest, hence agreement can be achieved via electronic platform that is most suitable during pandemic outbreak. The developed KPI framework can be considered as a prototype that was established and consented by experts without any bias; and it can be used in targeted setting after confirmatory or construct validation process. However currently, medical researchers rarely use FDM to obtain expert consensus on any subject matter. Delphi method should be widely used in medical related studies to obtain consensus among experts especially in developing a protocol, module or guidelines related to medical practices.[20-22] The Delphi method is well suited for research related to health education and health promotion campaigns, setting up guidelines or choice of clinical management.

FDM has an advantage of being able to rank the importance of selected items and remove the unfit items based on expert consensus and hence served as content validation process.[23,24] This study found that the average Likert scale scoring by the experts for all the items are from moderately to extremely appropriate range. However, in post FDM analysis, only nine items fulfilled all the pre-requisites. About 59% of the items did not match the terms, hence those items were regarded as failure to achieve consensus from the expert panel. These unfit items were the fuzziness or uncertainty among the expert panels that were not detected by the usual Likert Scale scoring system. Each expert has his/her own uncertainty towards certain variable, which often regarded as the "grey area". The use of FDM is to minimize those "grey area" effect and hence ensuring robust analysis. This method also catered for all experts' opinion, considering some experts are more experienced, some are more knowledgeable, some with relevant skills and some has the policy making authority in the field.[25,26] Variety of opinions is merged together to support each other's deficiency to derive at the desirable outcome. Moreover, the final draft of KPI framework was arranged based on priority ranking. Obviously, statement of items may have been interpreted differently among the experts. Any one

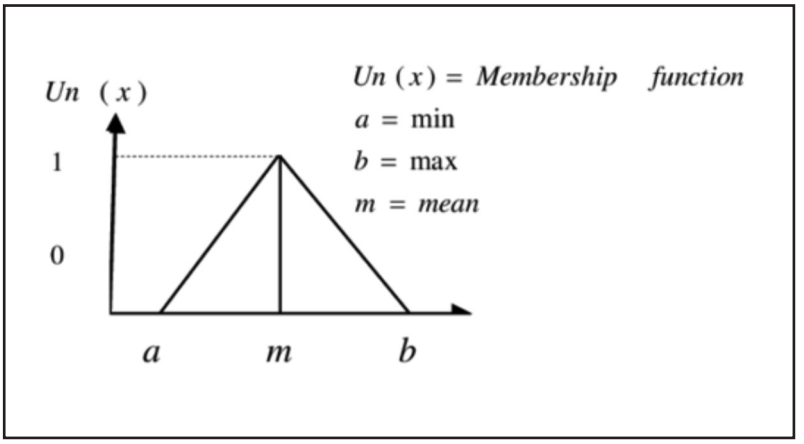

Fig. 1: The Triangular Fuzzy numbers.

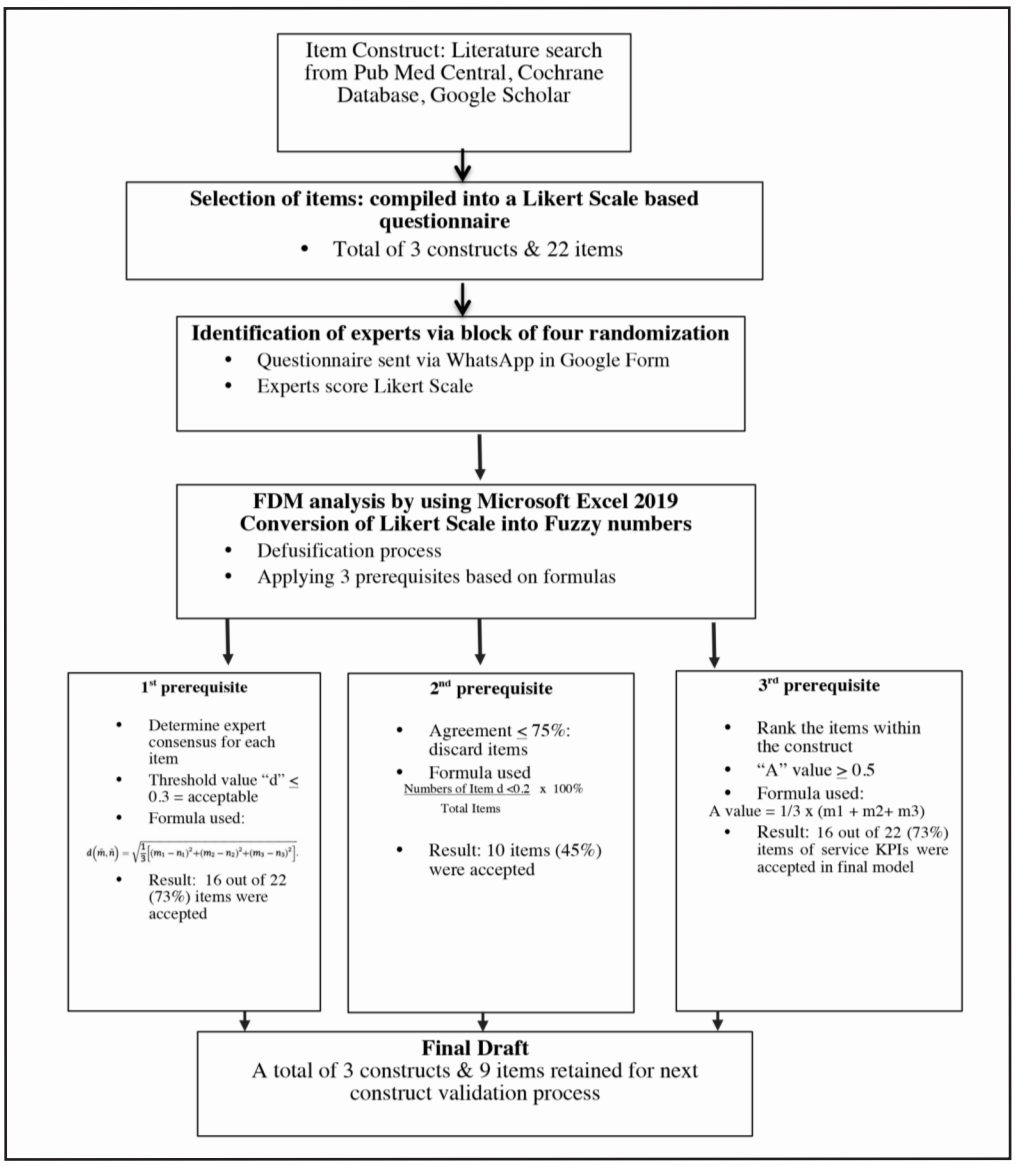

Fig. 2: Summary of content validation using Fuzzy Delphi Method for service KPI.

statement may have been well practiced KPI by the particular expert whereas the same KPI statement may deem to be non-crucial for other experts due to differences in set up of the ED of teaching hospitals. Additionally, the view of the experts may have been limited to their own and did not represent the view of whole fraternity. Unfortunately, no comments were obtained from experts on why they have put low marks on discarded items as by principle FDM works by giving Likert scale scoring without any commentary section or reasoning.

However, in the current pandemic situation, it is no doubt that FDM offers a very practical and safe method of getting expert opinion by a robust scientific technique and it is hoped that this study can serve as a guide for any future medical or health related research that intends to use FDM for their studies. The developed KPIs serve as a quality assurance tool for ED of teaching hospitals and can be replicated for similar use in non-teaching hospitals if deem suitable base on individual needs. KPIs allow stakeholders to identify critical issues that can be solved with low-cost actions, both in time and resources. The final outcome is to serve public and staff alike so that both sides gain benefit out of service provision in most efficient manner such as satisfaction, happiness index, and reduction in mortality and morbidity.

STRENGTH AND LIMITATIONS

However, the use of FDM in reaching expert consensus has its own strengths and limitations. The method can be used as a pre-construct validation tool to select the suitable items before subjecting it to a construct validation process. Most importantly, this method gives a proper quantitative approach to usual group discussions or meetings that are in a qualitative manner. The developed KPI items can be considered as accepted by the experts without any prejudice and it can be used for the targeted population after confirmatory validation process. The FDM process of obtaining expert consensus avoids the logistics issues pertaining to gathering of all experts such as tedious preparation, starting from the calling letter, arranging the venue and travelling expenses.[27] This method will certainly reduce the risk of bias by ensuring anonymity and welcoming the opinion of atypical views among the experts and the responses are totally independent without the fear of being judged by others that usually present in any routine group discussions or meetings. On the other hand, weaknesses of FDM include requirement of constant reminder to the experts to give their response and lead to the emotional bias among the experts. The KPI framework established in this study might not be applicable to other setting elsewhere. Different organisation may have other priorities in the KPI development that is more suited to their needs. The KPI developed has not been tested into real clinical setting hence it can be considered as a prototype. Further analysis is required for its applicability in the real setting before any improvement can be carried out.

CONCLUSION

FDM is applicable in medical research in obtaining experts' consensus on suitability of pre-selected items. The KPI set were obtained, hence it is now ready for further construct validation process and tests for its applicability in the real clinical service setting in teaching hospitals throughout the country.

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