Cardiothoracic Anesthesia, Respiration and Airway

The appropriateness of the pulmonary artery catheter in cardiovascular surgery

[La pertinence du cathéter artériel pulmonaire en chirurgie cardio-vasculaire]

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Purpose: The pulmonary artery catheter (PAC) is commonly used in anesthesiology and critical care, but its appropriate (where benefit exceeds risk) application is unknown. This study describes current clinical practice attitudes among anesthesiologists in cardiac and vascular surgery in an effort to determine the most appropriate indications for use of the PAC.

Methods: Anonymous, cross-sectional, mailed survey of anesthesiologists in Canada and the USA. Opinions of anesthesiologists about the appropriateness of PAC application were assessed in 36 clinical scenarios, using a nine-point Likert scale. The RAND method was adapted to identify appropriate, inappropriate, and uncertain indications for PAC application.

Results: Seventy-seven percent of 345 anesthesiologists responded. They agreed strongly (87%) that use of the PAC is appropriate in patients with severe ventricular impairment and unstable angina. Agreement was also present with ventricular impairment (74%) or unstable angina (55%) alone, but was less strong. A majority (53%) rated the PAC as not appropriate in the routine patient without complicating risk factors. Those who used the PAC more frequently, who had a greater practice volume, and who practised in Canada rated PAC use to be more appropriate in more scenarios. Those who did more continuing medical education rated PAC use to be less appropriate.

Conclusions: While the ideal evaluation of the PAC in clinical practice would be a randomized controlled trial, such an undertaking is time-consuming, expensive, of limited generalizability, and requires clinical equipoise. This study found strong agreement that PAC application is appropriate in some patient scenarios, and agreement that it is inappropriate in others. Description of current practice using this method may identify scenarios where randomized evaluation of the PAC, or other technologies, is likely unnecessary, and others where it is highly likely to be highly beneficial.

Objectif : *Le cathéter artériel pulmonaire (CAP) est fréquemment utilisé en anesthésiologie et aux soins intensifs, mais la pertinence (où les avantages dépassent les risques) de son application n'est pas connue. La présente étude décrit les attitudes de pratique courante des anesthésiologistes en chirurgie cardiaque et vasculaire dans le but de déterminer les indications les plus pertinentes de l'usage du CAP.*

Méthode : *Une enquête anonyme et ponctuelle a été postée à des anesthésiologistes du Canada et des États-Unis. L'opinion des anesthésiologistes sur la pertinence du CAP a été évaluée selon 36 scénarios cliniques en utilisant une échelle de Likert de neuf points. La méthode RAND a été adaptée pour préciser les indications pertinentes, non pertinentes et incertaines de l'application du CAP.*

Résultats : *Soixante-dix-sept pour cent des 345 anesthésiologistes ont répondu. Une forte majorité (87 %) appuyaient l'usage du CAP dans les cas d'atteinte ventriculaire sévère et d'angine instable. Un accord, moins important, se dessinait également pour l'atteinte ventriculaire (74 %) ou l'angine instable (55 %) seule. Une majorité (53 %) a jugé le CAP non pertinent chez le patient habituel sans facteurs de risque de complications. Ceux qui utilisent le CAP plus souvent, qui ont une clientèle plus importante et qui pratiquent au Canada ont jugé le CAP plus pertinent dans plus de scénarios. Ceux qui ont davantage suivi la formation médicale continue l'ont décrit comme moins pertinent.*

Conclusion : *L'évaluation idéale du CAP en clinique devrait faire l'objet d'un essai randomisé et contrôlé, mais cela demande du temps, coûte cher, ne présente qu'une généralisabilité limitée et exige une équipoise clinique. La présente étude a montré une adhésion solide à l'application du CAP comme pertinente chez certains patients et non pertinente chez d'autres. La description de la pratique courante fondée sur cette méthode peut définir les scénarios où l'évaluation randomisée du CAP, ou d'autres technologies, serait superflue et d'autres scénarios où il est fort probable qu'elle serait très avantageuse.*

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A major theoretical benefit of the pulmonary artery catheter (PAC) is the ability to acquire a large amount of physiologic data.[1–9] These data are expected to reduce uncertainty, facilitate diagnosis, and in some cases to direct interventions. As this theoretical benefit is coupled with a simple, low-risk (once central venous cannulation is accomplished) instrumentation, the PAC has diffused widely into clinical practice.

However, despite its common use, controversy about its application continues, because of conflicting and weak evidence.[6,10–14] At least two organizations (the American Society of Anesthesiologists and the Society of Critical Care Medicine) have developed guidelines for PAC application. These have been limited by broad generalizations.[15–18] Clinicians have had to rely on low levels of evidence, and incorporate their own experience, to guide PAC application.

Concerns about application of medical and surgical treatments have been addressed by the RAND corporation to describe indications for coronary artery angiography, angioplasty, and bypass grafting, among others.[19–21] "Appropriate" is defined as the circumstance where the benefit of a manoeuvre exceeds the risk, in usual clinical practice. Typically, expert clinicians have rated the appropriateness of the studied procedure, based on the best available evidence and their own clinical practice. Agreement among these clinicians is measured, and the conclusions of the expert panel are used to describe "indications" for the procedure studied.

The decisions of practising cardiovascular anesthesiologists regarding the "appropriate" application of the PAC are unknown. Informally, the likelihood of PAC application in similar scenarios appears to vary widely (Arthur Keats (2001), Andrew Clark (2001), personal communications).

The objective of this investigation was to determine the indications for appropriate PAC application during cardiovascular surgery, as defined by the opinion and usual approach of practising anesthesiologists. Factors related to the patient, practitioner, and practice setting that may influence assessment of appropriateness were addressed. It was also hypothesized that the ratings of appropriateness by practising clinicians would be related to patient disease, and to clinicians' volume and type of practice, amount and level of training, continuing medical education (CME) indicators, and country of certification, training and practice.

Methods

After receiving Institutional Ethics approval, a survey of all anesthesiologists from English-speaking hospitals in Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland was performed. Anesthesiologists from centres in Alberta participated, based on a known difference in remuneration structures. Finally, all anesthesiologists from randomly selected academic institutions in the United States participated, based on known differences in the availability of the transesophageal echocardiogram (TEE). These latter issues were important in addressing other components of this survey. Respondents were included if they described themselves as delivering at least one anesthetic for a cardiac or vascular procedure in an average month.

The survey instrument was mailed on January 13, 1998. Each was numbered and contained a return postcard and self-addressed, stamped, return envelop. A second mailing was performed to non-respondents one month later. Those still not responding were given a follow-up telephone call, and another mailing if requested. A second and final telephone call was done in the latter part of April 1998.

In the survey instrument, respondents were asked to rate the appropriateness of PAC use in 36 clinical scenarios, using a nine-point Likert scale, ranging from one (completely inappropriate) to nine (completely appropriate). The basic scenario was a typical 65-yr-old male undergoing elective coronary artery bypass grafting or abdominal aortic reconstruction, who had no confounding medical conditions. The following conditions were subsequently superimposed individually: aortic stenosis (not sufficiently significant to require surgery of itself), distant myocardial infarction (MI, more than six months previously), recent MI (less than three months previously), pulmonary hypertension, chronic stable heart failure, unstable heart failure (requiring hospitalization or treatment within the past month), renal insufficiency (not requiring dialysis) and renal failure (requiring dialysis). Respondents were then requested to rate the appropriateness of PAC use in each of these scenarios when unstable angina (exacerbation within the past month), severe left ventricular impairment (ejection fraction less than 40%), and finally both unstable angina and severe left ventricular impairment were superimposed. Respondents were asked a series of questions to determine their frequency of PAC use, number of cases done, preferences for either the PAC or the TEE, amount and level of training, age, gender, duration in practice, location of training and practice, and items related to CME.

Analysis

Responses were entered into a database using EpiInfo® (Public Domain Software, Centre for Disease Control,

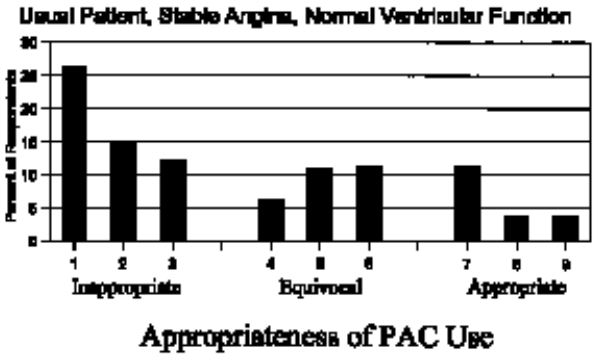

FIGURE 1 Usual patient, stable angina, normal ventricular function.

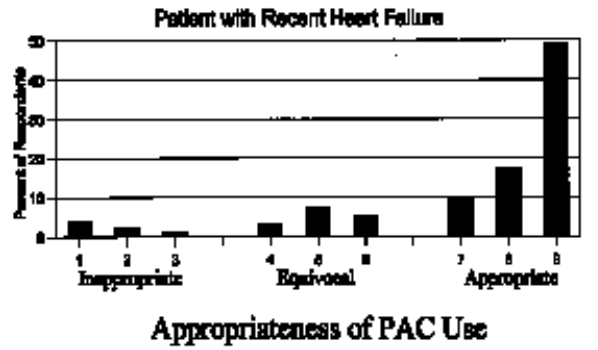

FIGURE 2 Patient with recent heart failure.

Atlanta, Georgia) and analysed using SAS version 6.0® (SAS Institute, Cary, NC, USA).

Respondents' ratings of appropriateness of PAC use were extracted from the nine-point Likert scale employed in each of the 36 scenarios. The frequency distributions were examined graphically, and were described using measures of central tendency (mean, mode) and spread (standard error). Respondents were instructed on the survey instrument that responses would be grouped as follows: inappropriate (rating 1–3), uncertain appropriateness (rating 4–6), and appropriate (rating 7–9).

Univariable analyses to compare appropriateness ratings with practitioner and practice characteristics were performed using analysis of variance for categorical and continuous variables. Multivariable analysis was subsequently performed in a reverse step-wise fashion. All practitioner and practice variables that had a "*P*" value less than 0.30 or which were clinically sensible were considered in the multivariable analysis. The multivariable model was reduced until all remaining variables had a *P* value less than 0.05. The frequency distributions of all appropriateness ratings were considered prior to univariable and multivariable analyses, to assess the goodness of fit of the linear, logarithmic, and logistic models. In each case, the best fit was obtained with the logistic model. Consequently, logistic regression was employed to assess the association between appropriateness ratings of PAC use and the independent variables.

Results

Three hundred forty-seven anesthesiologists at 29 centres were surveyed. Two had moved prior to mailing, and were deleted from the final sample, leaving 345. Two hundred and ten responded to the first mailing (60.9%), 46 to the second mailing (13.3%), and nine to either of the telephone calls (2.6%). The overall response rate was 76.8% (265 of 345). Of these 265, 214 (80.8%) described themselves as delivering at least one anesthetic in the average month for a cardiac or vascular surgical case, and completed the survey. Subsequent results are based on these 214 respondents.

For the baseline patient (Figure 1) with stable angina and normal ventricular function undergoing elective coronary artery bypass grafting or abdominal vascular surgery, a majority of anesthesiologists (53%) agreed that the PAC was not appropriate (score 1–3; mean score=3.81), and only 19% percent thought that the PAC was appropriate (score 7–9). When presented with most of the other scenarios, the opinion of anesthesiologists about PAC appropriateness was uncertain. These included distant MI (mean score 4.17), non-surgical aortic stenosis (mean score 4.8), renal insufficiency (not requiring dialysis, mean score 5.18), renal failure (requiring dialysis, mean score 6.27), recent MI (mean score 5.90), pulmonary hypertension (mean score 5.76), and a history of heart failure (mean score 6.15). However, they agreed that the PAC was appropriate in the patient with a recent exacerbation of heart failure (Figure 2, mean score 7.45).

With impaired ventricular function and stable angina, 74% agreed that the PAC was appropriate (Figure 3, mean score 7.19), and only 16 % thought the PAC was inappropriate. In patients with unstable angina but a normal ventricle, 55% agreed that the PAC was appropriate (Figure 3, mean 6.25). In patients with both unstable angina and ventricular impairment, 87% of anesthesiologists agreed that use of the PAC was appropriate (Figure 3, mean 8.24). The appropriateness ratings of all of the superimposed conditions

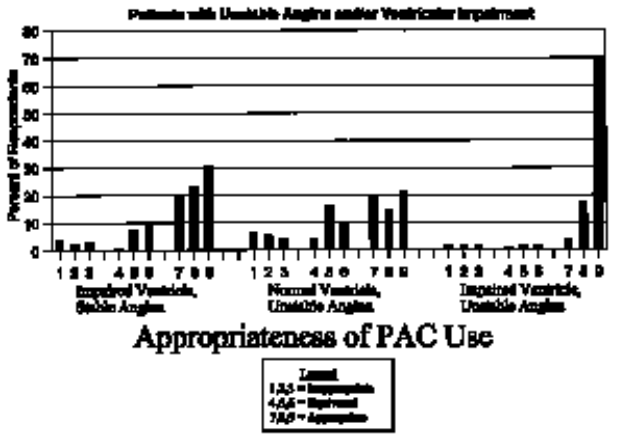

FIGURE 3 Patients with unstable angina and/or ventricular impairment.

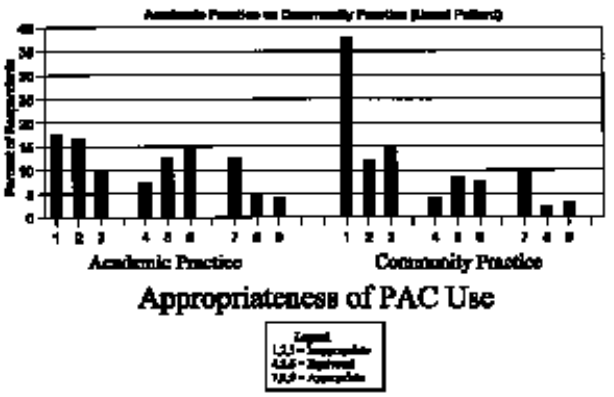

FIGURE 5 Academic practice *vs* community practice (usual patient).

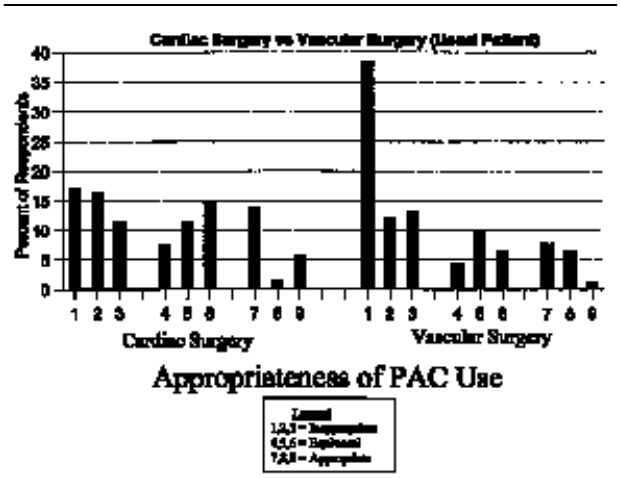

FIGURE 4 Cardiac surgery *vs* vascular surgery (usual patient).

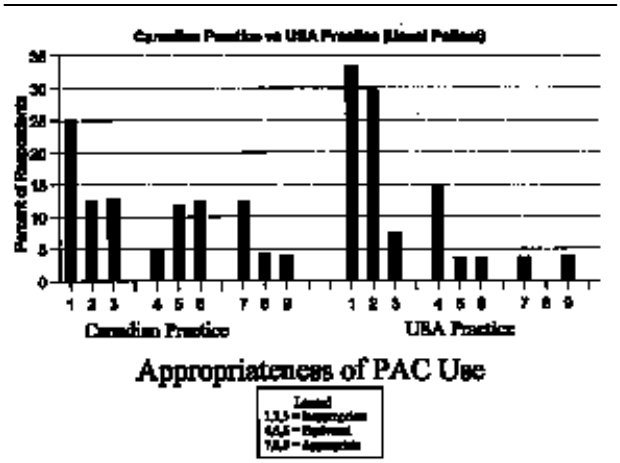

FIGURE 6 Canadian practice *vs* USA practice (usual patient).

(unstable angina, ventricular impairment, or both) were significantly different from each other at $P < 0.005$ (after correction for multiple comparisons, Table I), from the other medical conditions, and from the routine patient with no other medical conditions.

There were differences in the mean appropriateness scores according to respondent characteristics. PAC use during cardiac surgery (Figure 4, mean 4.25) had a higher appropriateness (P value 0.002) than its use in vascular practice (Figure 4, mean 3.19). In academic practice (Figure 5, mean 4.23), the appropriateness was higher than in community practice (mean 3.25, P value=0.004). PAC use by Canadian respondents (Figure 6, mean 3.96) was rated more appropriate than by US respondents (Figure 6, mean 2.74, P value=0.017).

In the multivariable analyses (Table II), the most significant associations were the positive ones between appropriateness and the proportion of cases in which the PAC was used (P=0.0001 in each scenario), as well as with the amount of practice (P=0.003 to P=0.03). The country of practice was highly associated with a rating of appropriateness (P=0.0001 to P=0.001), as those practising in Canada rated PAC appropriateness more highly than those practising in the USA. Attendance at

specialty society meetings was inversely associated with rating the PAC as appropriate (P=0.04). Other factors such as age, gender, level of post-graduate training, subspecialty certification, usual type of surgery (cardiac *vs* vascular), and practice type (academic *vs* community) were not significant.

Discussion

In this survey of practising anesthesiologists, a high response rate (77%) was achieved, which enhances the generalizability of the findings, and may reflect concern among respondents about the appropriate applications of the PAC.

Most anesthesiologists rated the PAC as appropriate in the patient with severe ventricular impairment and in the patient with unstable angina. In the patient with both severe ventricular impairment and unstable angina, virtually all anesthesiologists agreed that the PAC was appropriate. These two factors, especially in combination, outweighed the significance of any of the other factors.

Existing guidelines have emphasized PAC application according to a balance where the "benefit exceeds the risk".[10,15,22,23] The findings of this study complement and build on these earlier recommendations, by describing the composite best practice of clinicians.

A majority of respondents reported that the PAC in the routine patient undergoing elective cardiac revascularization or abdominal vascular reconstruction is inappropriate. Some authors have recommended that this patient group might be a reasonable starting point for a randomized evaluation of the PAC. However, the weight of clinical opinion in this study is that PAC use is unnecessary in these patients, which would make a randomized trial unethical.

Nonetheless, our observations are at variance with known practice, as PAC utilization rates approach 100% in some areas (M. Jacka (1995), unpublished data). Reasons for the difference between actual and "appropriate" practice might include regional variations in the approach to perioperative care, influence of other clinicians involved perioperatively for consultant or concurrent care, referral bias, a greater (or lesser) willingness to operate on patients with a greater (or lesser) degree of perioperative risk in some regions, and differing remuneration structures. Investigation directed at determining the contribution of these factors to observed practice variation may be beneficial.

The other clinical factors considered were rated as equivocal for PAC placement (i.e., mean scores of

TABLE I Effects on appropriateness ratings of PAC use of addition of unstable angina, ventricular impairment, or both, to usual patient (mean appropriateness)

Condition	*Appropriateness mean score*
1- Routine/baseline patient	3.81
2- Scenarios with Unstable Angina Only	6.23*
3- Scenarios with Ventricular Impairment Only	7.19*
4- Scenarios with both Unstable Angina and Ventricular Impairment	8.22*

* P value <0.0005 (1 *vs* 2, 1 *vs* 3, 1 *vs* 4, 2 *vs* 3, 2 *vs* 4, and 3 *vs* 4, after correction for multiple comparisons).

TABLE II Summary of multivariable analyses of independent variables associated with appropriateness of PAC use (odds ratio[1] (95% confidence limits), P value)

Descriptor	*Routine patient*		*Patient with unstable angina*		*Patient with ventricular impairment*		*Patient with unstable angina and ventricular impairment*	
	OR	*P* value	OR	*P* value	OR	*P* value	OR	*P* value
Proportionate of cases with PAC used [1] (≤ 75 % *vs* > 75 %)	0.13 (0.07, 0.22)	0.0001	0.24 (0.14, 0.41)	0.0001	0.19 (0.11, 0.33)	0.0001	0.28 (0.15, 0.55)	0.0002
Amount of practice (≤ 5 per month *vs* >5 per month)	0.50 (0.30, 0.85)	0.01	0.44 (0.25, 0.75)	0.003	0.55 (0.32, 0.94)	0.03	0.39 (0.20, 0.76)	0.006
Country of practice (USA *vs* Canada)			0.18 (0.08, 0.44)	0.0001	0.26 (0.12, 0.56)	0.0007	0.23 (0.10, 0.56)	0.001
Presentations at local rounds (≤ 1 per year *vs* >1 per year)	1.91 (1.02, 3.56)	0.04	1.93 (1.02, 3.66)	0.04				

[1]Odds ratio was calculated comparing the descriptor in parentheses on the left with that on the right e.g., the odds ratio of the pulmonary artery catheter (PAC) being rated as appropriate in the routine patient by those who used the PAC in less than 75% of cases to those who used the PAC in more than 75% of cases was 0.13.

4–6). The equivocal rating may be due to anesthesiologists' concerns about the technical limitations of the device itself, and the compromised reliability of the physiologic correlations necessary for its use.

The strongest association found in the multivariable analyses was with the frequency of PAC use (proportion of cases in which the PAC was used). This suggests that frequent PAC users might not discriminate among patients regarding the risk/benefit ratio of PAC application. Alternatively, this ratio may be overwhelmingly beneficial in the hands of frequent PAC users.

Physicians practising in Canada rated the appropriateness of the PAC much higher than those practising in the United States. Respondents trained in both Canada and the USA reported the use of the PAC as more appropriate than those trained in either country alone. Almost all of the respondents trained in both countries were practising in Canada. While it might be expected that training in another practice "environment" would lead one to adopt the practice of the "environment" visited, the opposite occurred in this study. Further study of the effect of differently-trained individuals on their colleagues' practice may be important.

Those in academic practice rated PAC appropriateness to be higher than those in community practice, as was true of those who usually gave anesthesia for cardiac surgery *vs* vascular surgery. Variation in the acuity of cases seen in academic centres may have had an effect on respondents' ratings. All of these groups described PAC use in the routine patient as inappropriate, with the vascular group agreeing more strongly than the cardiac group. The lower appropriateness rating in vascular surgery may reflect several factors, including a number of publications that reported no benefit of the PAC in abdominal vascular reconstruction.[22–28] A large randomized trial of the PAC in perioperative management of elderly patients was ongoing at multiple Canadian sites at the time of the survey, which included a substantial portion of abdominal vascular surgical patients (Dean Sandham (2001), personal communication), but not cardiac surgical patients. The fact that patients were being randomly assigned to receive the PAC or not, and being safely managed in either group, may have induced respondents to shift their routine practice to more selective PAC use.

While it is absolutely vital that randomized controlled trials be done, it is impractical to conduct them for the PAC in the multiple scenarios that should be considered.[29–31] There simply are not enough patients, nor enough time, to answer all relevant questions using RCTs. Practical surrogates need to be developed.

This study of the appropriateness of the PAC may be a suitable surrogate. The respondent clinicians have indicated that the PAC is appropriate in the patient with severe ventricular impairment, unstable angina, or both. Although these findings do not represent unequivocal evidence of benefit of the PAC, they summarize the current "best practice" of actual clinicians. This best practice should incorporate the limited published evidence, and the multiple other components of clinical care, many of which are difficult to measure, and some of which actually change because they are measured.[32] This strong consensus of opinion from practising users of the technology can be considered to be an indication that the benefit of the PAC in a patient with severe ventricular impairment or unstable angina exceeds the harm. Remaining are multiple states of clinical equipoise, where the risk/benefit balance is unknown. These included many combinations of disease and potential surgical applications, where further evaluation is advisable.

In summary, the appropriate application of the PAC remains unresolved, due to the absence of unequivocal evidence of benefit or harm. The ideal method to guide clinical practice, an RCT, remains elusive because of patient variation, entrenched practice patterns, financial, and temporal and other logistic constraints. This study described the current practice of anesthesiologists regarding appropriateness of PAC application in surgical scenarios. Respondents agreed that PAC use is appropriate in patients undergoing aortocoronary bypass grafting or abdominal vascular reconstruction who have a history of severe ventricular impairment, unstable angina, or both. They also agreed that the use of the PAC in the routine patient without comorbidity undergoing these surgeries is not appropriate. In multiple other scenarios, no agreement was found among respondents. Further use of this method to describe appropriate technology application may be beneficial.

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