Intraoperative detection of segmental wall motion abnormalities with transesophageal echocardiography

Pierre Couture MD FRCPC,*
André Y. Denault MD FRCPC,
Stéphane Carignan MD FRCPC,†
Daniel Boudreault MD FRCPC,
Denis Babin MSc,
Monique Ruel RN

Purpose: To compare two methods of analysis of regional wall-motion (RWM) using transesophageal echocardiography (TEE).

Methods: Thirty patients undergoing coronary artery bypass surgery were studied. The transgastric short axis view at the mid-papillary level was recorded before and after cardiopulmonary bypass. All images were reviewed by an anesthesiologist trained in TEE and an echocardiographer. Regional wall motion was graded: 1 normal, 2 hypokinetic, 3 akinetic, and 4 dyskinetic. The left ventricle was evaluated according to the guidelines of the American Society of Echocardiography using 6-segment, and 4-segment models. Agreement between observers (interobservers), and for one observer at two different moments (intraobservers), for grading each segment was defined as RWM abnormality scores within 1 grade. A wall-motion score index (WMSI), which is the sum of individual scores divided by the number of segments visualized, was calculated. A Bland Altman analysis was used to assess interobserver variability.

Results: Agreement between observers occurred in 96% and 94% of the examined segments, using 4- and 6-segment models respectively. Intraobserver agreement was 99% and 97% for the 4- and 6-segment models. The mean differences (bias) of the interobserver variability in grading the segments were 0.04 ± 0.79 and 0 ± 0.72 using a 4- or 6-segment model. The mean difference of the interobserver variability in WMSI were -0.05 ± 0.42 and 0.05 ± 0.37 using a 4- or a 6-segment model.

Conclusion: Both methods, using either a 4- or a 6-segment model, result in a high intraobserver and interobserver agreement, and a low interobserver variability.

Objectif : Comparer deux méthodes d'analyse de la motilité régionale de la paroi cardiaque (MRP) en utilisant l'échocardiographie transoesophagienne (ETO).

Méthode : Trente patients devant subir un pontage aortocoronarien ont participé à l'étude. L'incidence transgastrique dans son axe court au niveau médian du muscle papillaire a été enregistrée avant et après l'opération. Toutes les images ont été examinées par un anesthésiologiste spécialisé en ETO et un spécialiste en échocardiographie. La motilité régionale de la paroi a été graduée : 1, normale; 2, hypokinétique; 3, akinétique et 4, dyskinétique. Le ventricule gauche a été évalué selon les directives de l' American Society of Echocardiography en utilisant des modèles à 6 et à 4 segments. L'accord entre les observateurs (interobservateur) et entre les moments d'observation pour un même observateur (intraobservateur) quant à la gradation de chaque segment a été défini comme des scores d'anomalie de la MRP pour un niveau. Un indice de cotation de la motilité de la paroi (ICMP), qui représente la somme des scores divisée par le nombre de segments visualisés, a été calculé. Une analyse de Bland Altman a été utilisée pour l'évaluation de la variabilité entre les observateurs.

Résultats : L'accord interobservateur est survenu dans 96 % et 94 % des examens de segments, selon des modèles à 4 et 6 segments respectivement. L'accord intraobservateur a été de 99 % et 97 % pour les modèles à 4 et 6 segments. Les différences moyennes (biais) de la variabilité entre les observateurs dans la gradation des segments ont été de 0,04 ± 0,79 et de 0 ± 0,72 selon un modèle à 4 ou 6 segments. Les différences moyennes de variabilité entre les observateurs concernant l'ICMP ont été de -0,05 ± 0,42 et de 0,05 ± 0,37 selon un modèle à 4 ou 6 segments.

Conclusion : Les deux méthodes, avec modèle à 4 ou à 6 segments, ont présenté un degré élevé d'accord intraobservateur et interobservateur et une faible variabilité entre les observateurs.

From the Departments of Anesthesia,* and Radiology,† Montreal Heart Institute, 5000 Belanger Street East, Montreal, Quebec, Canada, H1T 1C8, and the Centre Hospitalier de l'Université de Montréal (CHUM), Pavillon Notre-Dame, 1560 Sherbrooke Street East, Montreal, Quebec, Canada, H2L 4M1.

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Address correspondence to: Dr. Pierre Couture, Phone: 514-376-3330 ext 3732; Fax: 514-376-8784; E-mail: pcouture@sympatico.ca

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RANSESOPHAGEAL echocardiography (TEE) is commonly used during coronary artery bypass graft surgery to monitor regional cardiac function.[1] Detection of regional wall-motion abnormalities (RWMAs) with TEE has been shown to be an earlier and more sensitive sign of ischemia than electrocardiography during cardiovascular surgery.[2,3] Moreover, RWMAs that persist to the end of surgery are predictive of poor outcome after cardiac surgery.[3]

The most commonly used imaging plane for myocardial ischemia monitoring with TEE is the transgastric short axis view at the level of the mid-papillary muscles.[2-4] While most studies evaluating intraoperative regional wall-motion have used a 4-segment model at the mid-papillary level,[2-4] the American Society of Echocardiography (ASE) has published guidelines describing a 16-segment model of the left ventricle, including 6 segments at the mid-papillary level.[5] The goal is to obtain sufficient detail to characterize the pattern of dysfunction in patients with ischemic heart disease. The location of the segments follows the perfusion territory of the three major epicardial arteries to facilitate the diagnosis of ischemic dysfunction.[6]

The guidelines of the ASE have not been evaluated to characterize regional wall-motion with TEE during the intraoperative period. The purpose of this study was to compare two methods of analysis of regional wall-motion[2,5] when used by an anesthesiologist trained in TEE and an echocardiographer.

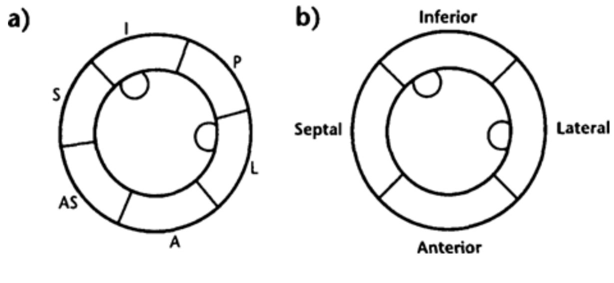
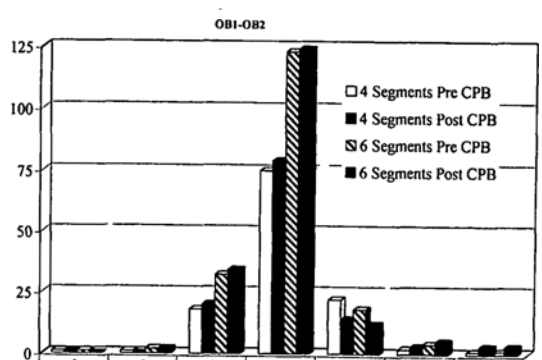


FIGURE 1 The left ventricle at the mid-papillary level was evaluated according to a) a 6-segment model, and to b) a 4-segment model. A, anterior, L, lateral, AS, anteroseptal, P, posterior, I, inferior, S, septal.



	-3	-2	-1	0	1	2	3
□4 Segments Pre CPB	1	1	18	75	22	2	1
■4 Segments Post CPB	1	0	20	79	14	3	3
▨6 Segments Pre CPB	1	2	32	123	18	4	0
■6 Segments Post CPB	0	2	34	124	12	5	3

FIGURE 2 Graphical display of the difference in grading the segments between observers. Each bar represents the number of segments in each category, for the 4- and 6- segment model, pre- and post- cardiopulmonary bypass.. Each category is on the X axis, 0 means that the gradings of segments were identical for the 2 observers, and 1, 2, and 3 represent the difference in grading the segments (observer 1 - observer 2). The difference can be negative when, for example, the first observer attributes a lower grade to a segment than the second observer. The table below the graph represents the numerical value for the number of segments depicted by each bar graph. CPB: cardiopulmonary bypass. OB1: observer no. 1. OB2: observer no. 2. OB1-OB2 is the difference in grading the segments between observer no. 1 and observer no. 2.

Methods

After institutional review board approval and written informed consent, 30 patients scheduled to undergo coronary artery bypass graft surgery (CABG), were studied. Patients with a history of dysphagia or esophageal disease were excluded.

Along with standard monitoring, intravascular arterial and pulmonary artery catheters were inserted, the latter after the induction of anesthesia. Thereafter, a 5.0-MHZ TEE multiplane probe, interfaced with a phased array imaging system (Hewlett Packard, Sonos 1500, Andover, Massachusetts) was inserted. The trans-gastric short axis view using TEE at the mid-papillary level was monitored, before and after cardiopulmonary bypass. All images were recorded on s-VHS tape for periods of 60 sec and reviewed independently by an anesthesiologist trained in TEE and an echocardiographer. The left ventricle at the mid-papillary level was first evaluated according to a 6-segment model (Figure 1): inferior, posterior, lateral, anterior, antero-septal, and septal.[5] Several days later, the left ventricle was re-evaluated according to a 4-segment model: inferior, lateral, anterior, and septal.[2-4] According to the recommendation of the ASE,[5] RWM was graded as follows: 1 normal, 2 hypokinetic, 3 akinetic, and 4 dyskinetic.

Agreement between observers for each segment was defined as RWM scores within one grade. This evaluation was repeated three months later by one observer to evaluate intraobserver agreement. We also calculated a wall-motion score index (WMSI) which is the sum of individual scores divided by the number of segments visualized.[5] A Bland Altman[7] analysis was used to assess interobserver variability (bias). A chi-square test was used to compare the number of segments within each category of wall-motion score between the two observers for the 4- and 6-segment models.

Results

Thirty patients were included in this study. A total of 600 segments were analyzed and none were excluded for analysis. Using a 4-segment model, agreement between the anesthesiologist and the echocardiographer occurred in 96% of the examined segments (score within 1 grade). When using the 6-segment model, the agreement reached 94%. Intraobserver agreement was 99% and 97% for the 4- and 6-segment models respectively. Figure 2 displays the difference in grading the segments between both observers, before and after the cardiopulmonary bypass.

Using bias analysis (Bland-Altman),[7] the mean differences (bias) of the interobserver variability in grading the segments were 0.04 ± 0.79 and 0 ± 0.72 using a 4- or a 6-segment model (Table I). The mean differences of the observer variability in WMSI were -0.05 ± 0.42 and 0.05 ± 0.37 using a 4- or a 6-segment model (Table I).

Table II shows the number of segments within each category of wall-motion score according to a 4- or 6-segment model of the left ventricle. No difference was found in the number of segments within each score of segmental wall-motion between both observers when using a 4- segment model. When using the 6-segment model, a discordance occurred in the interpretation of normal and hypokinetic segments between both observers, while no difference in the number of segments considered akinetic or dyskinetic were found. The echocardiographer graded more segments as normal (grade 1) (263 *vs* 230 segments) than the anesthesiologist ($P < 0.01$). On the contrary, the anesthesiologist scored more segments as hypokinetic (grade 2) than the echocardiographer (103 *vs* 62) ($P < 0.01$). Grouping grade 1 and 2 segments together, and considering these segments as normal or mildly abnormal, there was no difference in their analysis (325 *vs* 333 segments for the echocardiographer and anesthesiologist respectively). There was also no difference in the total number of segments graded 3 and 4, which were considered frankly abnormal, between both observers (32 *vs* 27, for the echocardiographer and anesthesiologist respectively).

TABLE I Interobserver variability of regional wall-motion

	RWM		*WMSI*	
	4-segment	*6-segment*	*4-segment*	*6-segment*
Mean difference (bias)	0.04	0	-0.05	0.05
Mean SD (precision)	± 0.79	± 0.72	± 0.42	± 0.37

RWM = regional wall-motion score, WMSI = wall-motion score index

Note: A Bland-Altman analysis was used to assess interobserver variability

TABLE II Number of segments within each category of wall-motion score according to a 4-and 6-segment models of the left ventricle

	Echocardiographer		*Anesthesiologist*	
	4-segment	*6-segment*	*4-segment*	*6-segment*
1	162	263*	157	230
2	51	62*	69	103
3	14	18	11	18
4	10	14	6	9

* $P < 0.01$ when both observer were compared for the 6-segment model. The total number of segments analyzed were 240 for the 4-segment model and 360 for the 6-segment model

Discussion

Intraoperative TEE monitoring during coronary artery bypass surgery is commonly used to detect RWMA. Our study evaluated two methods of analysis of RWM: a 4-segment model at the mid-papillary level [2–4] and a 6-segment model at the mid-papillary level according to the ASE guidelines.[5] In this study, we obtained a high degree of agreement (scores within 1 grade) between an anesthesiologist trained in TEE and an echocardiographer using either a 4- or a 6-segment model (96% and 94% respectively). The intraobserver agreement was also high for the 4- and 6-segment models (99% *vs* 97%, respectively). The mean bias between observers was small using either a 4- or a 6-segment model. Interestingly, we found that the precision between the observers was better (smaller standard deviation) when using the WMSI than the individual wall-motion scores. This could be due to interobserver variation in segmental boundary location, which is minimized by calculating WMSI when compared to the score obtained using WMS.

Despite the high degree of agreement for the total of segments analyzed and the small bias and good precision observed for the 4- and 6-segment models, we found a discordance in the interpretation of normal and hypokinetic segments using the 6-segment model. Indeed, the echocardiographer scored more segments as normal (grade 1) and the anesthesiologist scored more segments as hypokinetic segments (grade 2) with the 6-segment model. No difference were found for segments with frankly abnormal motion (akinetic and dyskinetic segments, grade 3 and 4 respectively). One possible explanation is that anesthesiologists have classically used another scoring system for regional wall-motion.[2–4] This 5-grade scale makes a difference between mild and severe hypokinesis and is described as follows: 1 normal, 2 mild hypokinesia, 3 severe hypokinesia, 4 akinesia, and 5 dyskinesia. The ASE recommendations used in this study[5] do not attribute different grades for mild and severe hypokinesia. It is possible that the anesthesiologist scored as hypokinetic (grade 2 of the ASE recommendations) some segments that were only mildly hypokinetic, which were scored normal by the echocardiographer. This finding, however, does not modify the agreement to score more dysfunctional segments, which are the akinetic and dyskinetic segments (grade 3 and 4 of the recommendations of the ASE). The consequence of this finding on the detection of intraoperative ischemia has not been evaluated in the present study because we did not perform continuous monitoring of the RWM.

The ASE most recent recommendation is a 16-segment model.[5] The goal is to obtain sufficient detail to characterize the pattern of dysfunction without overburdening the clinician. The locations of the segments follow the perfusion territory of the three major epicardial arteries and facilitate diagnosis of individual coronary artery stenosis.[6] The recommended standard assigns a score of 1 for normal function or hyperkinesis, 2 for hypokinesis, 3 for akinesis, and 4 for dyskinesis.[5] These guidelines have been previously validated in clinical studies comparing echocardiographic score with contrast ventriculography and radionuclide ventriculography.[11,12] These guidelines are also used in exercise and pharmacological stress echocardiography to discriminate between patients at low and high risk of developing ischemic events after myocardial infarction.[13] However, the role of these recommendations to detect ischemia in the intraoperative period and its relation to postoperative cardiac events after CABG surgery have not been evaluated. The use of the 6-segment analysis at the mid-papillary level follows the recommendation of the ASE and has the additional advantage of uniformity between anesthesiologists and other echocardiographers when compared with a 4-segment analysis. However, the 16-segment analysis may identify ischemic segments that are missed with the simplified 4- or 6-segment analysis and needs to be assessed in the intraoperative period.

Detecting wall-motion abnormalities may have prognostic importance.[3,4,8,9] Some investigators have identified a correlation between ischemic episodes detected by TEE during cardiac surgery and adverse cardiac outcome.[3,4] In one of these studies, Leung *et al.*[3] found an association between post-bypass wall-motion abnormalities and postoperative myocardial infarction following coronary artery bypass surgery. Thirty-three percent of patients with post-bypass ischemia had a myocardial infarction compared with 0% of patients without ischemia. More recently, Comunale *et al.*[4] reported that wall-motion abnormalities detected by TEE are more common than S-T segment changes detected by ECG, and that TEE is twice as predictive as ECG in identifying patients who have myocardial infarction (sensitivity 21% *vs* 45.2% to predict myocardial infarction for ECG and TEE respectively). Our results show a close agreement between the 4- and 6-segment models in detecting wall-motion abnormalities. While the use of the WMSI using the guidelines of the ASE has shown to be useful in determining prognosis after acute myocardial infarction,[10] its usefulness after CABG surgery has not been evaluated.

Limitations of our study include the TEE monitoring of only one cross section of the left ventricle in the transverse plane at the mid-papillary level. The use of multiple views of the left ventricle during TEE would result in increased detection of segmental wall-motion abnormalities.[14,15] Indeed, Rouine-Rapp *et al.*[15] found that 17% of the RWMAs detected were seen in the mid-papillary transverse plane cross section and that additional transverse planes increased the detection rate to 65%. Longitudinal-plane cross sections were required to detect many abnormalities (35%). We did not evaluate the usefulness of additional transverse or longitudinal cross sections to detect RWMAs. Future studies should assess the intraoperative use of the 16-segment model proposed by the ASE.[5] However, the mid-papillary transverse-plane cross section is actually the standard monitoring view to detect RWMA[2] and either the 4- or 6-segment result in a low interobserver variability. As another limitation, we studied baseline wall-motion, either before or after cardiopulmonary bypass and did not determine whether these wall-motion abnormalities were associated with myocardial ischemia. Importantly, generalization is one of the main limitations of this study, because our results reflect individual performance and experience of an anesthesiologist and an echocardiographer, in one specific institution. These results will have to be confirmed in a larger group of anesthesiologists with a training in intraoperative TEE. Finally, we assessed the WMS and the WMSI off-line in our echocardiography laboratory on images recorded on s-VHS tape. Real-time echocardiographic evaluation of regional wall-motion scores are subject to error and the interobserver agreement could have been different considering the increased complexity of evaluating 6-segment compared with the 4-segment model, particularly when other clinical responsibilities required attention.

In summary, we obtained a high degree of agreement (scores within 1 grade) between an anesthesiologist trained in TEE and an echocardiographer using either a 4- or a 6-segment model (96% and 94%) of the left ventricle at the mid-papillary muscle. A high intraobserver agreement was also obtained. Moreover, the bias and precision of either the 4- and 6-segments were small between the anesthesiologist and the echocardiographer, indicating that both methods could be used to assess the regional wall-motion during the intraoperative period. The usefulness of these guidelines in detecting real-time intraoperative myocardial ischemia and to predict postoperative myocardial infarction remains to be determined. It is also unknown if these results are applicable in other setting, particularly for individuals with more limited training.

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