RESEARCH

Prospective validation of a clinical decision rule to identify patients presenting to the emergency department with chest pain who can safely be removed from cardiac monitoring

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ABSTRACT

BACKGROUND: Most patients with chest pain in the emergency department are assigned to cardiac monitoring for several hours, blocking access for patients in greater need. We sought to validate a previously derived decision rule for safe removal of patients from cardiac monitoring after initial evaluation in the emergency department.

METHODS: We prospectively enrolled adults (age ≥ 18 yr) who presented with chest pain and were assigned to cardiac monitoring at 2 academic emergency departments over 18 months. We collected standardized baseline characteristics, findings from clinical evaluations and predictors for the Ottawa Chest Pain Cardiac Monitoring Rule: whether the patient is currently free of chest pain, and whether the electrocardiogram is normal or shows only nonspecific changes. The outcome was an arrhythmia requiring intervention in the emergency department or within 8 hours of presentation to the emergency department. We calculated diagnostic characteristics for the clinical prediction rule.

RESULTS: We included 796 patients (mean age 63.8 yr, 55.8% male, 8.9% admitted to hospital). Fifteen patients (1.9%) had an arrhythmia, and the rule performed with the following characteristics: sensitivity 100% (95% confidence interval [CI] 78.2%–100%) and specificity 36.4% (95% CI 33.0%–39.6%). Application of the Ottawa Chest Pain Cardiac Monitoring Rule would have allowed 284 out of 796 patients (35.7%) to be safely removed from cardiac monitoring.

INTERPRETATION: We successfully validated the decision rule for safe removal of a large subset of patients with chest pain from cardiac monitoring after initial evaluation in the emergency department. Implementation of this simple yet highly sensitive rule will allow for improved use of health care resources.

Chest pain is a common presentation to the emergency department, with more than 8 million visits annually, and accounts for about 5%–7% of all visits to emergency departments in the United States.[1,2] Ultimately, only 12%–15% of patients with chest pain who have a diagnosis of acute coronary syndrome, which includes ST-elevation myocardial infarction, non–ST-elevation myocardial infarction or unstable angina.[3] Most patients with chest pain are placed on a cardiac monitor in the emergency department for fear of a potentially life-threatening arrhythmia. Studies consistently show that arrhythmia is an uncommon event; among patients with chest pain who undergo continuous cardiac monitoring, 99.4% of monitor alarms were erroneous, with no arrhythmias detected.[4–6]

Cardiac monitors in the emergency department are a scarce resource, and patients with chest pain occupy a substantial proportion of monitored beds for a prolonged period of time. This effectively blocks access to these beds, with increased morbidity and mortality for other cardiac and noncardiac patients in crowded emergency departments.[7–10] In current practice, most patients with chest pain are triaged to an area with cardiac monitoring.[6] The decision to remove them from cardiac monitoring is based on individual physician gestalt, and emergency physicians have overwhelmingly acknowledged that research to identify low-risk patients for monitoring has the potential to substantially influence clinical practice and optimize resource use.[11,12] More than 90% of physicians stated that they would forgo cardiac monitoring among chest pain patients if an appropriate low-risk subset could be identified.[12] However, little work has been done to identify patients who are at risk for arrhythmia and the need for cardiac monitoring among these patients.

Our group previously prospectively derived a highly sensitive decision tool that identifies patients who can be safely removed from cardiac monitoring and reported that 1.7% of patients with chest pain in the emergency department had arrhythmias.[13] In this study, we sought to prospectively validate this decision rule to determine its safety and potential clinical impact.

Box 1: The Ottawa Chest Pain Cardiac Monitoring Rule[13]

A patient with chest pain can be removed from cardiac monitoring on initial physician assessment if:

- the patient is currently chest pain free
- and the patient's electrocardiogram is normal or has nonspecific changes (no signs of acute ischemia; infarction; bundle branch block; prolonged QRS, QT or PR interval; left ventricular hypertrophy with strain; arrhythmia; or paced rhythm).

Methods

Study design and setting

We conducted a prospective cohort study at 2 tertiary care emergency departments of The Ottawa Hospital (Civic and General campuses), each with about 75 000 patient visits per year. Both emergency departments have 2 main nursing stations for monitored beds (20 at the General campus, 23 at the Civic campus). All monitored beds are connected to a central control panel at the nursing station, with alarms and arrhythmia monitoring. Each nursing station is maintained by 3–4 nurses, and it is the nurses' responsibility to note alarms and changes in a patient's condition or vital signs.

Enrolment

From November 2013 to April 2015, we attempted to prospectively enroll consecutive patients who presented to the emergency department with chest pain (or with neck, back, shoulder or abdominal pain that was suspicious for a cardiac cause) and who were placed on cardiac monitor. Patients were excluded from the study if they had a cardiac arrest before arrival at the hospital or showed an ST-elevated myocardial infarction on an initial electrocardiogram (ECG).

The decision to place a patient on cardiac monitor was made at the triage nurse's discretion by taking the patient's Canadian Triage and Acuity Scale score into account.[14] This score is used to determine the urgency with which patients presenting to the emergency department require care and the frequency of reassessments while the patient is waiting. The scoring system does not make any explicit recommendations regarding placing patients in a monitored bed for physician assessment.

Patients gave verbal consent to participate in the study.

Data collection

This validation phase was conducted and data were collected as per the previously conducted derivation phase.[13] We collected the presenting symptom, the time of onset and whether the patient was free of chest pain. Similar to the derivation study, during the validation phase, ECGs were analyzed and classified by the investigators after the investigators were blinded to outcome data. The study was conducted in the context of a larger study that aimed to develop troponin cut-off values for ruling-in and ruling-out non–ST-elevation myocardial infarction among patients presenting to the emergency department with chest pain.

We created data collection forms before the beginning of the study with the required information. Data collection forms were appended to the charts of all potentially eligible patients by emergency department nurses, clerks or physicians. We collected baseline characteristics (age, sex), medical history (hypertension, diabetes, coronary artery disease or congestive heart failure), the presence of any pre-existing arrhythmia on arrival at the emergency department and the decision tool predictors. The Ottawa Chest Pain Cardiac Monitoring Rule (Box 1) comprises 2 clinical predictors: "Is the patient currently chest pain free?" and "Is the ECG normal or showing only nonspecific changes?" In addition, we collected the patient's disposition (discharged to place of residence or admitted to hospital).[13]

ECG analysis

All ECGs performed during the study patients' visits to the emergency departments were analyzed by the investigators (S.S., M.G.) after the visit. We classified the ECGs based on an internationally accepted classification for abnormalities as follows: 1 = normal; 2 = nonspecific ST–T wave changes, accepted deviation from the norm with a low likelihood of ischemia; 3 = abnormal, but not diagnostic of ischemia (i.e., prolonged QTc, QRS or PR intervals, atrial fibrillation or flutter, old rate-controlled arrhythmia, bundle branch block, left ventricular hypertrophy with strain or heart block); 4 = ischemia or infarction known to be old; 5 = ischemia or infarction not known to be old; 6 = consistent with acute myocardial infarction; and 7 = uninterpretable (paced rhythm).[15]

It is possible for ischemia to be detected in patients with paced rhythm using the Sgarbossa criteria.[16] However, because those criteria are not as well studied in this subgroup as in patients with left bundle branch block, we elected to code these ECGs as uninterpretable for ischemia.

The primary investigator (S.S.) was blinded to the patient outcomes and classified all of the ECGs. To determine interrater reliability, a second reviewer (M.G.), who was blinded to the first reviewer's classification and to the patient outcomes, reviewed all ECGs from a random sample of 100 study patients. For the purposes of the clinical prediction rule, the ECG classifications were dichotomized as normal or abnormal; ECGs in categories 1 and 2 were considered normal, whereas the remainder (categories 3–7) were considered abnormal.

Outcomes

We defined the outcome as an arrhythmia (defined as abnormal cardiac electrical activity) that occurred within 8 hours of presentation to the emergency department and which required treatment during the patient's stay in the emergency department. Ischemic or nonspecific ST wave changes were not considered arrhythmias. During the derivation phase, arrhythmias that occurred during the patient's stay in the emergency department

were defined as an outcome, with patients remaining in the emergency department for about 8 hours. However, with the use of newer troponin assays, to ensure that patients were not being discharged early only to have an arrhythmia outside the hospital, and to be consistent with the derivation phase, we included any arrhythmia within 8 hours of the initial presentation that required treatment as an outcome. Untreated arrhythmias and arrhythmias present on arrival during the initial emergency department visit were not considered an outcome.

We assessed the outcome occurrence by reviewing all emergency department records for the index visit. We reviewed physician record of treatment, nursing notes, medication administration records, procedural intervention notes and monitor strips. In addition, we reviewed all return visits within 24 hours of leaving the emergency department and conducted a standardized 30-day telephone follow-up by a trained research assistant to identify any arrhythmias that might have occurred after the visit. We collected information on the time of occurrence of these arrhythmias and the treatments received. We also collected 30-day outcome data (myocardial infarction, unstable angina or death) based on a review of medical records from the hospital and telephone follow-up.

Our study also included evaluation of outcomes among patients with chest pain who were not placed on cardiac monitoring. Safety data were collected for all patients who were not placed on a cardiac monitor to determine any potential adverse outcomes, arrhythmias or upgrade to monitor. We did this by reviewing records for the initial emergency department visit and any return visits within 30 days, a hospital chart review and a 30-day telephone follow-up to determine the occurrence of the study outcomes.

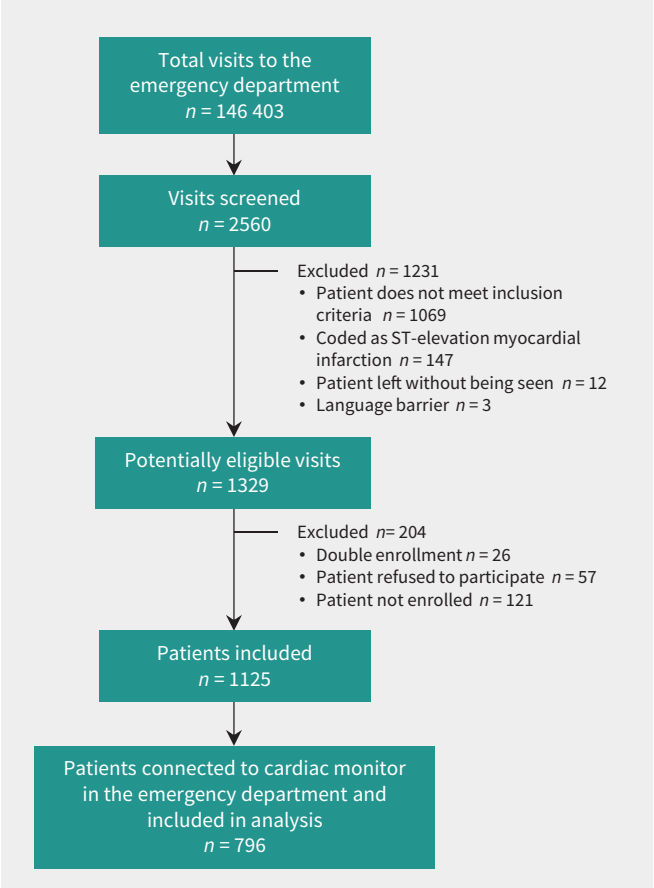

Figure 1: Flow of participants through the study.

Sample size

During the derivation phase, the Ottawa Chest Pain Cardiac Monitoring Rule performed with 100% sensitivity for predicting arrhythmias.[13] With a conservative estimation of 96% sensitivity during the validation phase, a 3% bound on the error and 1.5%–2% prevalence in the occurrence of arrhythmias, we calculated that 683 patients would be required to validate the tool.[17]

Primary data analysis

We used descriptive statistics to report patient characteristics using mean and standard deviations for continuous variables, and proportion with 95% confidence intervals (CIs) for categorical variables. We calculated interobserver agreement using the κ coefficient, the proportion of agreement beyond chance for classification of ECG abnormalities. We used χ^2 with continuity correction or the Fischer exact test as appropriate and reported relative risks with 95% CIs to determine the association between the rule pre-

Table 1: Baseline patient characteristics

Characteristic	Total, no. (%)* n = 796
Age, yr, mean ± SD	63.8 ± 14.8
Male sex	444 (55.8)
Coronary artery disease	286 (36.0)
Congestive heart failure†	48 (6.0)
Hypertension†	411 (52.0)
Diabetes†	157 (20.0)
Arrhythmia on arrival	
Atrial fibrillation/flutter	103 (12.9)
Paced	31 (3.9)
ECG	
Normal	315 (39.6)
Nonspecific ST–T wave changes	207 (26.0)
Abnormal, but not diagnostic of ischemia	209 (26.3)
Infarction or ischemia known to be old	34 (4.3)
Infarction or ischemia not known to be old	12 (1.5)
Uninterpretable	13 (1.6)
Missing ECG interpretation	4 (0.5)
Disposition and 30-day outcomes	
Admitted to hospital	71 (8.9)
Non–ST-elevation myocardial infarction	28 (3.5)
Unstable angina	32 (4.0)
Death	6 (0.8)

Note: ECG = electrocardiogram, SD = standard deviation.
*Unless otherwise specified.
†Diagnosis requires the patient to be on medication for these conditions.

dictors and study outcomes. We calculated sensitivity, specificity, predictive values and likelihood ratios with 95% CIs to report the performance of the clinical decision tool. We used SAS (version 9.4, SAS Institute Inc.) software for analysis.

Ethics approval

The Ottawa Health Science Network Research Ethics Board approved the protocol.

Results

A total of 1125 patients with chest pain were enrolled in the study, 796 of whom (70.8%) were monitored during their stay in the emergency department and included in our analysis (Figure 1). In our study, 8.9% of all patients were admitted to hospital (Table 1). Thirty-day clinical outcomes among study patients included 6 deaths (0.8%) within 30 days of presentation, none of which were due to arrhythmias and all of which had a non-arrhythmogenic cause.

Within our cohort of patients who were monitored, 15 (1.9%, 95% CI 1.1%–3.1%) had arrhythmia requiring intervention (Table 2). All arrhythmias were detected during the initial visit to the emergency department; no patients had the study outcome during a return visit within 8 hours. All 15 of these patients had an abnormal ECG as per the decision tool. On review of the 329 patients who were not triaged to cardiac monitoring, we found that none of them subsequently had an arrhythmia within 8 hours. Overall, 15 of the 1125 (1.3%, 95% CI 0.8%–2.2%) patients enrolled in the study (including the patients who were not triaged to cardiac monitoring) had clinically important arrhythmias.

The decision rule detected all 15 outcomes, with no patients missed. The decision rule therefore performed with a sensitivity of 100% (95% CI 78.2%–100%), specificity of 36.4% (95% CI 33.0%–39.6%) and a negative predictive value of 100% (95% CI 98.7%–100%) (Table 3). If the rule were applied, 36% (286 out of 796) of patients who were on cardiac monitoring would have been able to be safely removed from monitoring during the initial physician assessment.

The relative risks for the 2 rule predictors were as follows: ECG normal or nonspecific changes, 0.02 (95% CI 0.00–0.28), and patient is free of chest pain, 0.43 (95% CI 0.15–1.25) (Table 4). The interrater reliability between the 2 physicians for the abnormal ECG predictor was 0.84 (95% CI 0.73–0.95).

Discussion

We previously derived[13] a simple and highly sensitive decision rule to remove patients from cardiac monitoring in the emergency department, and have subsequently validated the rule with the current study. Our study results show that clinically important arrhythmias are uncommon among patients presenting to the emergency department with chest pain. A substantial number of patients are unnecessarily being placed on cardiac monitoring,

Table 2: Description of patients who had arrhythmias and their subsequent treatments

Patient	Age, sex	Ongoing pain	ECG	Event	Intervention
1	33, M	Yes	Abnormal, not ischemic	Atrial fibrillation	Diltiazem intravenously
2	68, F	No	Abnormal, not ischemic	Atrial fibrillation	Magnesium sulfate intravenously, atenolol orally
3	67, F	Yes	Ischemic	Atrial fibrillation	Electrical cardioversion
4	68, M	Yes	Paced	Ventricular tachycardia	Amiodarone intravenously
5	51, M	No	Abnormal, not ischemic	Atrial fibrillation	Procainamide intravenously, electrical cardioversion
6	71, F	No	Abnormal, not ischemic	Atrial flutter	Metoprolol intravenously
7	56, M	Yes	Abnormal, not ischemic	Atrial flutter	Diltiazem intravenously
8	58, F	No	Abnormal, not ischemic	Supraventricular tachycardia	Diltiazem intravenously
9	73, F	No	Abnormal, not ischemic	Atrial fibrillation	Procainamide intravenously
10	79, M	Yes	Abnormal, not ischemic	Atrial fibrillation	Digoxin, electrical cardioversion
11	67, F	Yes	Abnormal, not ischemic	Atrial fibrillation	Magnesium sulfate and diltiazem intravenously
12	85, M	No	Abnormal, not ischemic	Atrial fibrillation	Metoprolol intravenously
13	80, F	No	Abnormal, not ischemic	Atrial fibrillation	Diltiazem intravenously, electrical cardioversion
14	67, M	No	Abnormal, not ischemic	Supraventricular tachycardia	Adenosine and metoprolol intravenously
15	79, F	No	Abnormal, not ischemic	Atrial fibrillation	Metoprolol intravenously

Note: F = female, M = male.

while this resource is needed for patients in the waiting room who are more ill. This validated rule will help identify a large subset of very low-risk patients with chest pain who could safely be removed from cardiac monitoring at the onset of their evaluation in the emergency department.

During the validation phase, less than 2% of patients had arrhythmias, and these results are similar to those from the derivation phase. However, all patients who had arrhythmias would have been identified by our decision rule. The American Heart Association suggests that all patients presenting to the emergency department with chest discomfort or other symptoms suggestive of acute coronary syndrome be placed on cardiac monitoring during work-up, although there is very limited evidence to support this recommendation.[18] Given the escalating degree of emergency department crowding in North America, we believe it is impractical to place all patients on cardiac monitoring during their entire stay for work-up of acute coronary syndrome.

In our study, the most common arrhythmia that required intervention within 8 hours was atrial fibrillation, or flutter. It is possible the fast ventricular rates associated with this arrhythmia could have caused the patients' chest pain and their presentation to the emergency department.

The Ottawa Chest Pain Cardiac Monitoring Rule was derived to achieve a very high sensitivity (100%) and performed at this level of sensitivity during the validation phase. As with most decision rules that involve a potential serious outcome, we feel that the high sensitivity is the most important characteristic of the rule, because we are attempting to ensure that patients do not have increased morbidity and mortality as a result of missed arrhythmias.

Our study identified a large subset of low-risk patients with chest pain who can be safely removed from cardiac monitoring during their stay in the emergency department. We feel that this is a clinically important finding, because the ability to remove about one-third of patients with chest pain from cardiac monitoring at the beginning of their evaluation potentially unburdens enough monitored beds to positively affect flow and alleviate crowding in the emergency department. In addition, the interrater agreement for ECG interpretation in our study was very good, 0.84, and was similar to the 0.80 calculated during the derivation phase.[19]

This study does not aim to dictate which patients require cardiac monitoring, but identifies a subset of patients who may be removed from cardiac monitoring at the time of the initial physician evaluation. In our study, the predictors were assessed by physicians validating the rule. The predictor "Is the patient chest pain free?" can potentially be evaluated by the triage nurse on initial patient contact in the emergency department. If the patient is free of chest pain, and the physician confirms that the ECG is normal or shows only nonspecific changes, we recommend that the patient be triaged to a nonmonitored area in the absence of any distress or unstable vital signs. However, further studies are needed to assess the success of implementation at triage.

Decision rules are developed to aid management decisions when uncertainties exist. Any patient who looks unwell or has unstable vital signs should be placed on a monitor regardless of the rule, because no decision rules are required in the management of care for such unstable patients.

In our study, the outcome was defined as an arrhythmia requiring intervention within 8 hours of arrival at the emergency department. Because arrhythmias beyond 8 hours during a stay in hospital or in the short term were not used in the analysis, we are unable to provide recommendations for inpatient telemetry among patients admitted to hospital with potential acute coronary syndrome. Further research involving patients admitted to hospital should be completed to answer this question.

We gave consideration to the incorporation of troponin results in the decision-making process for removing patients from cardiac monitoring. One previous study that incorporated the results of the first troponin in their algorithm found no decrease in the duration of cardiac monitoring.[20] Given the 100% sensitivity with the 2 simple predictors in our rule, the ease of its application and the results of the previous study, we believe that incorporating troponin results will lead to lesser impact on health resource use.

Table 3: Performance of the Ottawa Chest Pain Cardiac Monitoring Rule among participants with arrhythmia

Performance	Arrhythmia	No arrhythmia	Total
Rule positive	15	497	512
Rule negative	0	284	284
Total	15	781	796

Note: Sensitivity = 100% (95 % confidence interval [CI] 78.2%–100%), positive likelihood ratio = 1.57 (95% CI 1.49–1.66), positive predictive value = 2.9% (95% CI 1.7%–4.8%), specificity = 36.4% (95% CI 33.0%–39.6%), negative likelihood ratio = 0.0, negative predictive value = 100% (98.7%–100%).

Strengths and limitations

The strengths of our study include its prospective design, rigorous data collection, analysis and follow up, and strong interrater reliability for the abnormal ECG predictor. In addition, we feel

Table 4: Performance of the Ottawa Chest Pain Cardiac Monitoring Rule predictors

Predictor	Outcome occurred, % *n* = 15	Outcome did not occur, % *n* = 781	RR (95% CI)
Patient is free of chest pain	5 (33)	423 (54)	0.43 (0.15–1.25)
ECG normal or nonspecific	0 (0)	523 (67)	0.02 (0.00–0.28)

Note: CI = confidence interval, RR = relative risk.

that this clinical problem has a broad geographic scope of applicability because patients with chest pain are typically placed on cardiac monitoring in North America, Australia and Europe.

Our study does have several limitations. Given that arrhythmia is an uncommon event in patients presenting with chest pain, a very large sample size will be required to achieve more precise estimates of sensitivity. However, because the patients not on a cardiac monitor will still be in the emergency department, we believe the consequent morbidity and mortality will be low.

A small proportion of eligible patients (121 of 1246 patients; 9.7%) were not enrolled because the emergency physicians were busy and did not complete the study form. However, with more than 90% of eligible patients enrolled, we believe that these missing patients will not bias the study results.

To keep the study forms short and improve physician compliance, we did not ask attending physicians to interpret the ECGs, and therefore potentially lost some pragmatic value.

The initial derivation study classified the ECGs as "normal or nonspecific ECG" or "abnormal" if signs of acute ischemia, infarction, old infarction, left bundle branch block or paced rhythm were present. Since the publication of the derivation study, standardized definitions for research into acute coronary syndrome have been developed.[15] Hence, we elected to use these standardized definitions. These standardized definitions included QRS and QT prolongation, old arrhythmia, right bundle branch block and left ventricular hypertrophy with strain pattern as "abnormal." Despite the standardized definition being more conservative and more inclusive, our study maintained an improved specificity compared with the initial derivation study. We believe that these standardized definitions will make widespread implementation easier.

We acknowledge the lag time between derivation and validation studies, but we do not feel that this interval affects the results in a meaningful way. Both the derivation and validation studies were done at the same institution, which is considered temporal validation of the prediction model.[21] Hence, future studies completed in a different population may be useful in further affirming the external validity of the decision rule.

We did not specifically collect information on patients whose chest pain resolved after treatment or those in whom chest pain developed later while fulfilling criteria on initial physician assessment. We believe that it is unlikely to affect the results of our study because all 15 patients who had arrhythmia showed an abnormal ECG as per the rule. In these scenarios, we believe the rule should be applied at the discretion of the physician.

Our study results show that a 36% reduction in monitoring can be achieved by implementing the Ottawa Chest Pain Cardiac Monitoring Rule. However, depending on differences in ECG interpretation and provider nonadherence, the actual reduction might be lower than reported here.

Conclusion

We found that arrhythmia among patients presenting to the emergency department with chest pain is an uncommon event, which is consistent with previously published studies. We successfully validated a simple and highly sensitive clinical decision rule to safely remove patients from cardiac monitoring. Based on our results, we recommend that patients who present to the emergency department with chest pain be removed from cardiac monitoring if they are free of chest pain at the time of assessment and if the ECG is either normal or shows only nonspecific changes. Following this rule will allow for at least one-third of patients to be safely removed from cardiac monitoring immediately after their initial evaluation, freeing up valuable resources that may be allocated to patients who are more ill.

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Contributors: Shahbaz Syed, Mathieu Gatien, Jeffrey Perry and Venkatesh Thiruganasambandamoorthy conceived the idea for this study. All of the authors contributed to the study design and development of the study protocol. All of the authors were involved in the conduct of the trial, including patient recruitment, data collection and data management, including quality control. Kenneth Kwong and Venkatesh Thiruganasambandamoorthy were involved in the statistical aspects of the study and analyzed the data. Shahbaz Syed, Mathieu Gatien and Venkatesh Thiruganasambandamoorthy drafted the manuscript. All of the authors reviewed the manuscript and contributed substantially to its revision, approved the final version to be published and agreed to act as guarantors of the results.

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