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Improved Patient Outcomes When Transmyocardial Revascularization Is Used as Adjunctive Revascularization

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ABSTRACT

Background: Transmyocardial revascularization (TMR) has been recently used to treat patients with angina for whom angioplasty/stenting and/or coronary artery bypass grafting (CABG) is no longer an option.

Methods: A retrospective review of 255 consecutive patients who required CABG was done. Group 1 patients (n = 219) underwent complete revascularization with CABG alone. Group 2 patients (n = 36) received CABG plus TMR. TMR was performed in regions of nongraftable coronary targets. Indications for surgery in both groups were Canadian Cardiovascular Society angina scores III or IV and an ejection fraction ≥30%. Exclusion criteria were an emergency procedure within 12 hours, unstable angina, or an acute myocardial infarction within 72 hours. Thirty-day outcomes of the two groups were compared. The means ± SD of patient ages (63.3 ± 1.6 years versus 65.4 ± 1.4 years) and ejection fractions (51.6% ± 0.9% versus 48.5% ± 1.6%) were similar for the two groups.

Results: The number of grafts performed and operating room times for the two groups were similar (3.1 ± 0.1 versus 2.9 ± 0.1 and 276.7 ± 4.4 minutes versus 272.3 ± 10.7 minutes, respectively). Intensive care unit times and lengths of stay (emergency room to discharge) were significantly shorter in the CABG plus TMR group (2.1 ± 0.2 days versus 1.6 ± 0.2 days [$P < .001$] and 8.2 ± 0.4 days versus 7.1 ± 0.6 days [$P < .001$], respectively). The 30-day readmission rate was lower in the CABG plus TMR group (7.8% versus 2.8%; $P < .5$). The frequency of atrial fibrillation was also significantly lower in the CABG plus TMR group (37.4% versus 16.7%; $P < .025$). Major adverse outcomes, such as reoperation for bleeding, respiratory failure, renal failure, stroke, and mortality were similar in the two groups, although there were no mortalities in the CABG plus TMR group.

Conclusion: TMR as an adjunctive revascularization to CABG in selected patients with limited options may improve in-hospital outcomes.

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INTRODUCTION

Transmyocardial revascularization (TMR) was introduced as a treatment for refractory angina in patients for whom percutaneous transluminal coronary angioplasty, stenting, or coronary artery bypass grafting (CABG) is no longer an option [Sen 1968, Cooley 1996, Allen 1999, Burkhoff, 1999]. Significant 12-month, 2-year, and 5-year improvements in angina relief, reductions in medication use, and improvements in exercise tolerance have been demonstrated [Horvath 1996, Horvath 2001].

Adjunctive procedures offer strategies for the surgeon when options are limited [Prendergast 2001]. Recent studies demonstrate that TMR can be added during the CABG procedure to regions of the left ventricle where the coronary artery target is not amenable for grafting [Allen 2000]. Additional data suggest that adjunctive TMR is associated with improved outcomes, such as 1-year survival benefit, when used in combination with CABG [Allen 2000, Stamou 2002].

The purpose of this study was to identify patients who may demonstrate benefit in terms of improved in-hospital outcomes when hybrid TMR is added to CABG.

METHODS

We retrospectively reviewed the outcomes of 255 consecutive patients who underwent either a CABG alone or a CABG plus TMR procedure during a 6-month period. All patients underwent their procedures at a single institution by 1 of 6 board-certified cardiac surgeons. All surgeons were certified by accredited training courses for TMR, and the procedure was approved by the hospital review board of the Peninsula Regional Medical Center. Appropriate informed consent was obtained from each patient prior to the prospective procedure.

TMR was performed in selected patients who met the inclusion and exclusion criteria. Holmium:YAG laser (CardioGenesis Corporation, Foothill Ranch, CA, USA) TMR was used in combination with CABG for coronary artery targets ≤1.0 mm. TMR was added to a CABG after the completion of all grafting. When the procedure was performed with the cardiopulmonary bypass machine, TMR was added after grafting and before completion of cardiopulmonary bypass and with a full left ventricle. If a surgical target was marginal and both a bypass graft and TMR were used in the same region of the ventricle (also described as the "belt and suspenders" technique), the patient was excluded from the study (n = 2) for comparison purposes.

Table 1. Preoperative Characteristics*

	CABG + TMR (n = 36)	CABG (n = 219)	*P*
Age, y	63.3 ± 1.6	65.4 ± 1.4	NS
Preoperative EF, %	51.6 ± 0.9	48.5 ± 1.6	NS
Previous CABG, %	11.1	5.5	.24
Preoperative CHF, %	8.3	27.9	.10

*Data are presented as the mean ± SD where applicable. CABG indicates coronary artery bypass grafting; TMR, transmyocardial revascularization; NS, not significant; EF, ejection fraction; CHF, congestive heart failure.

The following patient selection criteria were used. Indications for surgery for both groups were Canadian Cardiovascular Society angina scores (CCSAS) of III or IV and severe 3-vessel coronary artery disease (diameter lumen reduction ≥75% as determined by coronary angiography or intravascular coronary ultrasound). Exclusion criteria in both groups included patients with ejection fractions ≥30% (as determined by left ventriculography, nuclear medicine stress thallium analysis, and/or transthoracic echocardiography), patients who required an emergency revascularization procedure within 12 hours, and patients with a diagnosed acute myocardial infarction within 72 hours. Acute myocardial infarction was defined in our institution as those patients with elevated levels of troponin or creatine kinase myocardial enzymes, non–Q-wave myocardial infarctions, or Q-wave myocardial infarctions. Patients who developed persistent unstable angina despite continuous intravenous infusions of nitrates and antiplatelet medications were also excluded in both groups. In-hospital outcomes for the two groups were compared. Statistical comparisons were achieved with the Fisher exact test and the *t* test. Significance was considered for *P* levels <.5.

RESULTS

During a 6-month period at the Peninsula Regional Medical Center in Salisbury, Maryland, 36 patients with an ejection fraction ≥30 % with CCSAS III or IV angina underwent a combined CABG plus TMR procedure. Two hundred nineteen patients with similar criteria underwent a primary CABG procedure during this same period. Table 1 gives demographic data for each group. There were no statistical differences in age and preoperative ejection fraction between the groups. A higher percentage of patients in the CABG plus TMR group underwent a redo sternotomy and coronary revascularization procedure (11.1% [n = 4] versus 5.5% [n = 12]). A significantly greater percentage of patients in the group with CABG alone had congestive heart failure symptoms (27.9% [n = 61] versus 8.3% [n = 3]) in addition to class III or IV angina.

Table 2 presents the operative outcomes for the two groups. The numbers of grafts, total operative times, and ventilatory times were similar in the two groups. Intensive care unit times (days) and the length of stay (defined as number of days from the emergency room to discharge) were significantly shorter in the CABG plus TMR group. Similarly, the postoperative length of stay was significantly shorter in the CABG plus TMR group (6.7 ± 0.6 days versus 7.5 ± 0.7 days). Readmission within 30 days was also significantly reduced in the CABG plus TMR group. Inotropic use was similar in both groups.

Table 2. Perioperative Outcomes*

	CABG + TMR	CABG	*P*
No. of grafts	2.9 ± 0.1	3.1 ± 0.1	NS
OR time, min	272.3 ± 10.7	276.7 ± 4.4	NS
Ventilatory time, h	9.4 ± 2.5	9.9 ± 1.2	NS
Inotropes, %	11.1	15.1	NS
ICU time, d	1.6 ± 0.2	2.1 ± 0.2	<.001
LOS (ER to discharge), d	7.1 ± 0.6	8.2 ± 0.4	<.001
LOS (postoperative), d	6.7 ± 0.6	7.5 ± 0.7	.01
Readmit 30 d, %	2.8	7.8	.48

*Data are presented as the mean ± SD where applicable. CABG indicates coronary artery bypass grafting; TMR, transmyocardial revascularization; NS, not significant; OR, operating room; ICU, intensive care unit; LOS, length of stay; ER, emergency room.

Major adverse outcomes are shown in Table 3. The frequency of reoperation for bleeding was lower in the CABG plus TMR group (n = 1; 2.8%) than in the group with CABG alone (n = 15; 6.8%). Atrial fibrillation was significantly reduced in the CABG plus TMR group (n = 6; 16.7%) compared with the group with CABG alone (n = 82; 37.4%). None of the 36 patients in the CABG plus TMR group had respiratory or renal failure, compared with 3.6% (n = 8) and 2.7% (n = 6), respectively, in the group with CABG alone. Mortality was zero in the CABG plus TMR group and 2.3% (n = 5) in the group with CABG alone. Preoperative and 1 month postoperative angina scores were similar in both groups (Figure).

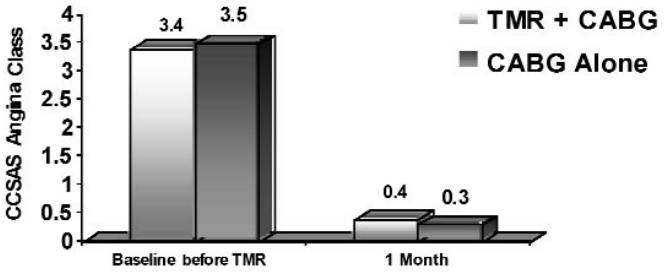
DISCUSSION

The benefits of TMR for providing angina relief are well documented. Reports from carefully controlled studies of both TMR as sole therapy [Allen 1999, Burkhoff 1999] and combined CABG plus TMR [Allen 2000] demonstrate significant angina relief, improved exercise tolerance, and improved quality of life. Our results support these studies and show that CABG plus TMR provides symptomatic relief of

Table 3. Major Adverse Outcomes*

	CABG + TMR	CABG	*P*
Atrial fibrillation, %	16.7	37.4	.025
Reoperative bleeding, %	2.8	6.8	.46
Respiratory failure, %	0	3.6	.60
Renal failure, %	0	2.7	.59
Neurologic complications, %	2.8	1.4	.80
Mortality, %	0	2.3	.80

*CABG indicates coronary artery bypass grafting; TMR, transmyocardial revascularization.



Angina improvement following coronary artery bypass grafting (CABG) procedures with and without transmyocardial revascularization (TMR). CCSAS indicates Canadian Cardiovascular Society angina score.

angina at 30 days that is comparable to that of patients who have "complete" revascularization with CABG alone.

Thirty-day and 1-year survival benefit has been demonstrated in patients receiving TMR in combination with CABG when patients are deemed not amenable to complete revascularization with CABG alone [Allen 2000]. Our results support these data by showing that perioperative mortality is lower when TMR treatment is added to CABG in patients who would have been incompletely revascularized.

Other short-term benefits of adjunctive TMR with CABG are largely unknown, partly because of inherent limitations in the study. A surgeon's intraoperative decision to perform TMR or grafting or both is a subjective one. This subjective bias may be influenced by the surgeon's attempt to achieve a more complete revascularization by adding more grafts to coronary arteries that are less-than-optional targets. This strategy could possibly affect outcomes if the suboptimal native coronary artery was compromised during graft anastomosis and led to perioperative myocardial ischemia or infarction. A recent study suggested that the availability of TMR may affect intraoperative strategy [Prendergast 2001]. Our data suggest that the strategy of performing TMR in a region of less-than-optional targets, rather than performing bypass grafts, may be associated with improved short-term outcomes.

Recent studies have targeted the development of strategies to improve in-hospital outcomes. In the present study, patients who underwent adjunctive TMR with CABG had shorter intensive care unit times, shorter postoperative times and overall lengths of stay, and fewer major adverse outcomes than those patients who received complete revascularization by CABG alone. Explanations for the differences are likely related to patient selection. Significantly more patients in the group with CABG alone had preoperative congestive heart failure symptoms and class III and IV angina symptoms, even though the patients in this group had similar ejection fractions. On the other hand, significantly more patients in the CABG plus TMR group had a redo sternotomy. Evidence suggests that procedures involving redo sternotomy and CABG are independent risk factors for major adverse outcomes. However, this subset of patients had fewer adverse outcomes in the present study. Perhaps the strategy of not performing grafts to questionable targets but performing TMR in that region instead may contribute to improved outcomes.

In this retrospective review, patients with end-stage coronary disease who were not amenable to complete revascularization by CABG alone underwent CABG plus TMR. This report suggests that if appropriate criteria are used for selecting patients, such as class III or IV angina symptoms only, an ejection fraction >30%, no acute myocardial infarction within 72 hours, and no emergent procedure within 12 hours, TMR plus CABG is safe and effective. Our study also suggests that adjunctive TMR with CABG in these selected patients is associated with decreased intensive care unit times, shorter postoperative and overall lengths of stay, lower 30-day readmission rates, and lower operative mortality rates. Randomized, prospective, multicenter trials with more patients are needed to confirm these findings. Follow-up of these selected patients is required to evaluate the long-term outcomes of CABG plus TMR.

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