Effects of Intra-Aortic Balloon Pumping on Graft Flow in Coronary Surgery: An Intraoperative Transit-Time Flowmetric Study

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Background. We investigated hemodynamic effects of intra-aortic balloon pumping (IABP) in in-situ and aorta-coronary (A-C) grafts during coronary artery bypass grafting (CABG).

Methods. One hundred seventy-two grafts, including 84 in-situ left internal thoracic arteries (LITAs), were examined intraoperatively with a transit-time flowmeter in 84 patients who had prophylactic IABP. The following measurements were obtained for each graft during off-IABP and on-IABP: mean flow, maximal flow, pulsatility index, and diastolic filling index. Coronary angiograms were performed 14 ± 5 days after coronary artery bypass graft surgery to verify the patency of the grafts.

Results. All measurements of 163 patent and measurable grafts were significantly increased with IABP: mean flow 46 ± 27 to 51 ± 29 mL/min; maximal flow 87 ± 52 to 121 ± 69 mL/min; pulsatility index 2.2 ± 1.4 to 3.1 ± 1.4; and diastolic filling index 64% ± 8% to 71% ± 9% ($p < 0.001$). Among them, the degrees of increase of mean flow and diastolic filling index were significantly different between the in-situ LITAs and A-C grafts (mean flow 18% ± 20% versus 10% ± 15%, $p = 0.04$; diastolic filling index 10% ± 8% versus 14% ± 9%, $p = 0.04$).

Conclusions. IABP assist significantly increases graft flow and also diastolic components of flow. The degree of increase is greater in the in-situ LITA supplying the left anterior descending artery than in A-C grafts anastomosed to other coronary arteries. IABP increases the diastolic component more in A-C grafts than in in-situ LITAs, probably because of different flow characteristics of the two grafts.

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Among patients with coronary artery disease, intra-aortic balloon pumping (IABP) has been widely used in patients with cardiogenic shock and low cardiac output syndrome [1–3]. The synchronized counterpulsation produced augmentation of diastolic pressure and also reduction of cardiac afterload resistance with decreased systolic pressure [4]. It has been used in cardiac surgery, as well as in diagnostic and therapeutic coronary catheterization. The IABP provides circulatory support for patients experiencing postoperative hemodynamic instability, especially as an aid in weaning from cardiopulmonary bypass [5, 6]. Furthermore, IABP has been more frequently used prophylactically in high-risk patients undergoing cardiac surgery [7–9]. Although the efficacy of IABP has consistently been demonstrated, the effects of IABP on coronary bypass graft flow remain uncertain. In the present study, we investigated the hemodynamic effects of IABP support upon graft flow in coronary artery bypass graft surgery (CABG), especially comparing the effects on in-situ versus aorta-coronary (A-C) graft flows.

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Material and Methods

Study Patients

The study group comprised 84 patients (59 men and 25 women, aged 65 ± 9 years), who underwent CABG with the assist of prophylactic IABP. They were 74% of all patients who underwent CABG during the same period. The preincision prophylactic IABP was indicated for one of the following reasons: left main trunk disease, left ventricular dysfunction (left ventricular ejection fraction < 0.40), emergency, and severe cerebrovascular or carotid disease. The study protocol was approved by the Institutional Review Board of our hospital. Written informed consent for the study was obtained from each patient before the surgery.

Just before anesthesia induction, an 8F sheathless IABP with a 34 mL balloon catheter (TRUE8-Super Track; Edwards Lifescience, Irvine, California) or 7.5F IABP with a 25 mL balloon (TOKAI 7Fr-Clear; Tokai Medical Products, Kasugai, Japan) was inserted percutaneously under fluoroscopic guidance into the descending thoracic aorta, with its tip just distal to the aortic arch. The IABP catheter was connected to a System 98XT (Datascope, Montvale, New Jersey), triggered by the electrocardiogram signal, and regulated manually to make the balloon inflation occur immediately after the aortic dicrotic notch and to adjust its deflation on the R wave of the electrocardio-

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Abbreviations and Acronyms

A-C	= aorta-coronary
CABG	= coronary artery bypass graft surgery
DFI	= diastolic filling index
IABP	= intra-aortic balloon pumping
LAD	= left anterior descending artery
LCX	= left circumflex artery
LITA	= left internal thoracic artery
PI	= pulsatility index
Qd	= diastolic flow
Qm	= mean flow
Qs	= systolic flow
RA	= radial artery
RCA	= right coronary artery
SVG	= saphenous vein graft

gram. The patients received 172 grafts including 84 in-situ left internal thoracic arteries (LITAs), 31 radial arteries (RAs), 50 saphenous vein grafts (SVG), and 7 in-situ right gastroepiploic arteries, with (n = 38) or without (n = 46) cardiopulmonary bypass. All LITAs were anastomosed with the left anterior descending artery (LAD), while the target vessels of the A-C grafts were 49 left circumflex arteries (LCX), 31 right coronary arteries (RCA), and 8 diagonal branches. Combined procedures included mitral valve plasty (n = 4), mitral valve replacement (n = 2), aortic valve replacement (n = 2), and abdominal aneurysmectomy (n = 2).

Intraoperative Graft Flow Measurement

Graft flow tracing was obtained intraoperatively using a transit-time flowmeter (BF 2000; Medi-Stim AS, Oslo, Norway). A flow probe of 2 or 3 mm was placed around the graft during the hemodynamic stabilization period with and without use of IABP just before the chest closure. Based upon the obtained flow profile, the following variables were calculated: mean graft flow (Qm, mL/min); maximal flow; pulsatility index (PI = [maximal − minimal flow]/Qm); and diastolic filling index ($DFI = 100\int Qd/[\int Qs + \int Qd]$), where Qd is diastolic flow and Qs is systolic flow based upon the definition that the systole is the duration from the peak of R wave to the peak of T wave in electrocardiogram-gated flow analysis. The flow profiles were obtained continuously during the IABP support of 1:1 (IABP on) and were also obtained after IABP was stopped for the 20 cardiac beats (IABP off). The

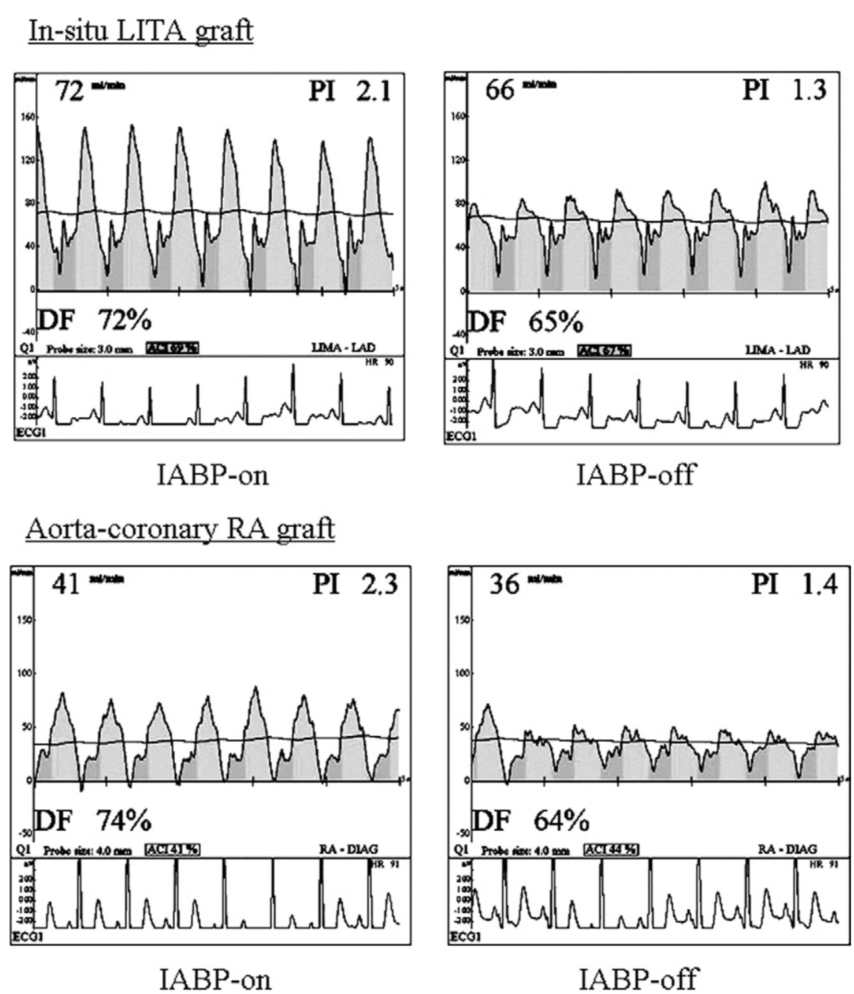

Fig 1. Intraoperative recordings of transit-time flow measurement in a 76-year-old woman. The electrocardiogram-gated analysis identifies systolic (dark shadow) and diastolic (bright shadow) components of the graft flow, calculating diastolic filling index (DFI). (Upper Panel) In-situ left internal thoracic artery (LITA) anastomosed with the left anterior descending artery (LAD): mean graft flow (Qm) = 66 mL/min, pulsatility index (PI) = 1.3, DFI = 65% during intra-aortic balloon pump off (IABP-off); and Qm = 72 mL/min, PI = 2.1, DFI = 72% during IABP-on. (Lower panel) Aorta-coronary graft of radial artery (RA) anastomosed with the diagonal branch (DIAG): Qm = 36 mL/min, PI = 1.4, DFI = 64% during IABP-off; and Qm = 41 mL/min, PI = 2.3, DFI = 74% during IABP-on.