Coronary Bypass Graft Fate

Angiographic Grading of 1400 Consecutive Grafts
Early after Operation and of 1132 after One Year

Gerald M. FitzGibbon, L.R.C.P. & S. (Ireland), Jeffrey R. Burton, M.D., and Alan J. Leach, M.D.

SUMMARY All 1400 coronary bypass grafts, in 409 survivors of 414 patients undergoing 440 consecutive bypass operations, were selectively opacified in multiplane cineangiograms prior to hospital discharge and 1132 (81%) were restudied at one year. Grafts were graded A (excellent), B (fair) or O (occluded) by separate assessment of proximal and distal anastomoses and bypass trunks. In early graft studies 89% were patent (A and B), 79% graded A; at one year, 81% were patent, 74% graded A. Circumflex-marginal grafts fared less well, but similarly late, compared with other grafts. Of all grafts graded B early, 37% became A, 39% remained B and 24% were occluded at one year; 90% of early graded A grafts remained so, 4% became B and 6% occluded; the grading system seems to have had useful predictive value. Distal anastomosis defects dictated early B grading in 81.3% of cases, trunk defects in 12.5% and proximal anastomosis defects in 2.7%. Trunk defects carried a worse prognosis for occlusion than did distal anastomosis defects. Side-to-side, vein-coronary anastomoses had a significantly higher patency rate than terminal end-to-side coronary anastomoses with the same veins.

CORONARY BYPASS GRAFTING will not become definitive treatment for coronary stenosis until its effectiveness in correcting myocardial perfusion deficit has been demonstrated conclusively. Further, apparent relief of ischemia, suggested by historical or functional criteria, requires support by morphologic data. To ensure this, a sufficiently large number of consecutively fashioned grafts must be studied and assessed using criteria more specific than “patent” or “occluded.”

Prior to postoperative hospital discharge, we have examined, by selective angiography in multiple planes, all 1400 coronary bypass grafts placed in a series of patients consecutively operated on between 11 November 1971 and 10 November 1976; the only exclusions were grafts of patients dying perioperatively. Our policy is to reexamine coronary bypass grafts, using precisely the same technique, approximately one year after operation. By the time of writing we have already examined 1132 (81%) of the original 1400 grafts. We have devised a simple method for grading the

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three portions of a bypass graft and applied it to all the
grafts examined.

Methods

Patient Population

The series contained 414 patients of mean age 45.6 years,
39% aged 35–44, 61% aged 40–49 and 90% aged 35–54. Most
were members of the Canadian Armed Forces or the Royal
Canadian Mounted Police and all but one were men. All 414
patients had operations involving coronary bypass grafting,
25 undergoing 26 reoperations, which also included bypass
grafting, for a total of 440 operations. Five patients did not
survive the initial operation’s hospital phase but there were
no deaths following re-operations. Hospital mortality for
440 operations was 1.14%. Excluding six patients also hav-
ing valve replacements for concomitant rheumatic heart dis-
ease, but including 100 with internal mammary implants and
35 having left ventricular aneurysm repair in addition to cor-
onary bypass grafting, mortality during the postoperative
hospitalization period was 0.46%. In the course of the 440
operations, 1410 coronary bypass grafts were placed or 3.2
grafts per patient; 46% of initial operations involved fashion-
ing four or more grafts (table 1). Ten grafts were lost to
follow-up by early patient death.

Of the 1400 coronary bypass grafts studied, 29% were to
branches of the circumflex-marginal system, 28% to the
anterior descending coronary artery, 25% to trunk or
branches of the right coronary artery and 18% to diagonal
branches of the anterior descending coronary artery (table 2).
Three-quarters of the bypasses were single-outlet reversed
saphenous veins, a small number were of the branched “Y”
type with two outlets and about one-fifth were sequential
anastomosis (SEQA) veins or saphenous venous trunks with one or more side-to-side anastomoses and a termi-
nal end-to-side anastomosis. There were 12 internal
mammary-coronary bypass grafts. In our specific detailing
and discussion of results each coronary anastomosis has
been considered to be the distal end of a single bypass graft,
irrespective of the trunk configuration. Preoperative study of
all patients was done at the National Defence Medical Cen-
tre (NDMC) but surgical procedures were performed at the
Cardiac Unit of the University of Ottawa, Ottawa Civic
Hospital. All operations were undertaken by one of the three
senior members of the Cardiac Unit’s surgical team.
Operations employed the technique of normothermic anoxic
cardiac arrest during fashioning of distal anastomoses.
Saphenous veins were removed from any suitable area and
not specifically, for instance, from the lower legs. Patients
were returned to the NDMC early after operation, usually
48 hours, and postoperative management thereafter, includ-
ing all specific examinations, became the responsibility of
the Cardio-Pulmonary Unit (CPU) of the NDMC.

Follow-up Angiograms

Two or three weeks after operation, in addition to other
studies including a treadmill exercise test, coronary
angiography was repeated using the Judkins technique and,
concomitantly, all bypasses in all surviving patients were
selectively intubated and opacified with contrast medium in
at least four planes. These included the 60° right anterior
oblique, postero-anterior, 45° left anterior oblique, and left
lateral. These multiplane examinations were facilitated by
using a parallelogram “U” arm. Almost all bypasses, in-
cluding internal mammary arteries, were intubated with a
Judkins #4 right coronary artery catheter. When coronary
venous bypasses were occluded proximally, care was taken
to produce angiographic evidence of this either as a short
length of patent graft or a dimple on the aortic wall; also, in
studying the native coronary circulation, careful attention
was paid to collateral evidence of graft occlusion. Marking
proximal (aortic) venous bypass ostia by radio-opaque loops
tied around vein trunks, and the consistent operating habits
of the surgeons, made selective opacification of vein grafts
quite easy. On no occasion was it necessary to find or to

<table>
<thead>
<tr>
<th>Table 1. Grafts per Operation*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operation</strong></td>
</tr>
<tr>
<td>Initial operation</td>
</tr>
<tr>
<td>Reoperation</td>
</tr>
<tr>
<td>All operations</td>
</tr>
</tbody>
</table>

*10 grafts lost to follow-up by death of five patients (at initial operation) leaving 1400 grafts for study.

<table>
<thead>
<tr>
<th>Table 2. Bypass Grafts by Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coronary artery grafted</strong></td>
</tr>
<tr>
<td>Right</td>
</tr>
<tr>
<td>Circumflex-marginal</td>
</tr>
<tr>
<td>Anterior descending</td>
</tr>
<tr>
<td>Diagonal branch of anterior descending</td>
</tr>
<tr>
<td>All arteries</td>
</tr>
</tbody>
</table>

*a graft implies a single distal anastomosis, i.e., a "Y" vein is classified as two grafts.
**A SEQA (sequential anastomosis) vein is a venous trunk with one or more side-to-side anastomoses and a terminal end-to-side anastomosis, each anastomosis being a graft.
diagonal to demonstrate a graft by large bolus injection of contrast medium into the aortic root.

Patients were followed regularly in the Out-Patient Clinic of the CPU. Unless earlier examination was dictated by a change in symptomatic status or a changed treadmill exercise test, patients were re-admitted approximately one year after operation for angiographic examination precisely similar to that undertaken early after operation. When preparing this publication, 1132 (E) had been restudied. Unless preparing this publication, 1132 in 1132 (E) had been restudied. All patients were re-admitted approximately one year after operation for angiographic examination precisely similar to that undertaken early after operation. When preparing this publication, 1132 coronary bypass grafts (81% of the original 1400) had been restudied. No early or late follow-up examination was abandoned for any reason and all films were acceptable for study.

### Table 3. Graft Patency and Grading Early and Late after Operation

<table>
<thead>
<tr>
<th>Coronary artery grafted</th>
<th>Series*</th>
<th>Number of grafts</th>
<th>A (%)</th>
<th>B (%)</th>
<th>A + B (Patent) (%)</th>
<th>O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>1400</td>
<td>354 (25)</td>
<td>290 (82)</td>
<td>29 (8)</td>
<td>319 (90)</td>
<td>35 (10)</td>
</tr>
<tr>
<td>1132(E)</td>
<td>292 (26)</td>
<td>238 (82)</td>
<td>24 (8)</td>
<td>262 (90)</td>
<td>30 (10)</td>
<td></td>
</tr>
<tr>
<td>1132(L)</td>
<td>292 (26)</td>
<td>222 (76)</td>
<td>19 (7)</td>
<td>241 (83)</td>
<td>51 (17)</td>
<td></td>
</tr>
<tr>
<td>Circumflex-marginal</td>
<td>1400</td>
<td>402 (29)</td>
<td>291 (72)</td>
<td>56 (14)</td>
<td>347 (86)</td>
<td>55 (14)</td>
</tr>
<tr>
<td>1132(E)</td>
<td>315 (28)</td>
<td>224 (71)</td>
<td>46 (15)</td>
<td>270 (86)</td>
<td>45 (14)</td>
<td></td>
</tr>
<tr>
<td>1132(L)</td>
<td>315 (28)</td>
<td>221 (70)</td>
<td>25 (7)</td>
<td>244 (77)</td>
<td>71 (23)</td>
<td></td>
</tr>
<tr>
<td>Anterior descending</td>
<td>1400</td>
<td>387 (28)</td>
<td>315 (81)</td>
<td>30 (8)</td>
<td>345 (89)</td>
<td>42 (11)</td>
</tr>
<tr>
<td>1132(E)</td>
<td>323 (29)</td>
<td>262 (81)</td>
<td>26 (8)</td>
<td>288 (89)</td>
<td>35 (11)</td>
<td></td>
</tr>
<tr>
<td>1132(L)</td>
<td>323 (29)</td>
<td>247 (77)</td>
<td>20 (6)</td>
<td>267 (83)</td>
<td>56 (17)</td>
<td></td>
</tr>
<tr>
<td>Diagonal branch of anterior</td>
<td>1400</td>
<td>257 (18)</td>
<td>213 (83)</td>
<td>17 (7)</td>
<td>230 (90)</td>
<td>27 (10)</td>
</tr>
<tr>
<td>1132(E)</td>
<td>292 (18)</td>
<td>167 (83)</td>
<td>16 (8)</td>
<td>183 (91)</td>
<td>19 (9)</td>
<td></td>
</tr>
<tr>
<td>1132(L)</td>
<td>202 (18)</td>
<td>152 (75)</td>
<td>15 (8)</td>
<td>167 (83)</td>
<td>35 (17)</td>
<td></td>
</tr>
<tr>
<td>All arteries</td>
<td>1400</td>
<td>1400 (100)</td>
<td>1109 (79)</td>
<td>132 (10)</td>
<td>1241 (89)</td>
<td>159 (11)</td>
</tr>
<tr>
<td>1132(E)</td>
<td>1132 (100)</td>
<td>891 (79)</td>
<td>112 (10)</td>
<td>1003 (89)</td>
<td>129 (11)</td>
<td></td>
</tr>
<tr>
<td>1132(L)</td>
<td>1132 (100)</td>
<td>842 (74)</td>
<td>77 (7)</td>
<td>919 (81)</td>
<td>213 (19)</td>
<td></td>
</tr>
</tbody>
</table>

*Series 1400 is all 1400 grafts placed in 409 survivors of 440 consecutive coronary bypass operations. Series 1132(E) is number of grafts (81% of 1400) re-examined late after approximately one year. Series 1132(L) comprises same grafts forming series 1132(L) but as graded at early examination.

Statistical Methods

All statistical analyses were done using the Chi-square method.

### Results

Table 3 displays graft patency grading for all 1400 grafts studied early and for the 1132 examined both early and one year after operation. The composition of the 1400 and 1132 Early series and the results of early grading of all 1400 and

### Table 4. Late Status of Grafts Graded A or B at Early Study

<table>
<thead>
<tr>
<th>Coronary artery grafted</th>
<th>Total graft number</th>
<th>Early grading</th>
<th>Number graded A or B (%)</th>
<th>Grading at 1 year</th>
<th>A (%)</th>
<th>B (%)</th>
<th>O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>292</td>
<td>A 283 (82)</td>
<td>215 (90)</td>
<td>10 (4)</td>
<td>13 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B 24 (8)</td>
<td>7 (29)</td>
<td>9 (38)</td>
<td>8 (33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circumflex-marginal</td>
<td>315</td>
<td>A 224 (71)</td>
<td>204 (91)</td>
<td>3 (2)</td>
<td>17 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B 46 (15)</td>
<td>18 (39)</td>
<td>19 (41)</td>
<td>9 (20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior descending</td>
<td>323</td>
<td>A 262 (81)</td>
<td>236 (90)</td>
<td>12 (5)</td>
<td>14 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B 26 (8)</td>
<td>11 (42)</td>
<td>8 (31)</td>
<td>7 (27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagonal branch of anterior</td>
<td>202</td>
<td>A 167 (83)</td>
<td>147 (88)</td>
<td>7 (4)</td>
<td>13 (8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B 16 (8)</td>
<td>6 (31)</td>
<td>8 (50)</td>
<td>3 (19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All arteries</td>
<td>1132</td>
<td>A 801 (79)</td>
<td>801 (90)</td>
<td>33 (4)</td>
<td>57 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B 112 (10)</td>
<td>41 (37)</td>
<td>44 (39)</td>
<td>27 (24)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*% of total graft number.
†% of number graded A or B.
of the 1132 subgroup grafts are almost identical and no statistically significant differences exist. Considering the grafts to all arteries, A grades were assigned early to 79%, B grades to 10% and O grades to 11%. After one year, in the 1132 Late series, 74% of grafts were graded A, 7% graded B and 19% were occluded. No statistically significant differences were evident between the results for grafts to the right coronary artery, the anterior descending vessel and the latter’s diagonal branches. However, grafts to branches of the circumflex-marginal coronary arterial system showed, in the early studies, a 10% lower rate of A grafts, a 7% higher rate of B grafts and a 4% higher incidence of graft occlusion. These early results for circumflex-marginal grafts are significantly different from those for the other grafted vessels (P < 0.0005). Table 3 suggests that the results may be similar for the 1132 Late series but statistical analysis does not validate a significant difference at one year between circumflex-marginal and other coronary artery grafts.

The validity of our grading system really depends on accurate distinction between A and B grafts. We have attempted to test this by examining, in the 1132 graft subgroup, the status at one year of those grafts graded A or B at the early examination (table 4). Considering early graded B grafts to all coronary arteries, 37% had become A, 39% had remained B and 24% had occluded at one year; the fate of early graded A grafts to these vessels was quite different (P < 0.0005), 90% remaining A, 4% becoming B and 6% suffering occlusion.

Table 5 examines early graded B grafts in greater detail, relating their status at one year to the specific defect which dictated B rather than A grading. Of the 112 grafts graded B at the early examination 81.3% had distal anastomosis defects, including intragraft coronary stenosis, and 12.5% had defects in the graft trunk, but only 2.7% had defects at the proximal anastomosis. Furthermore, although distal graft defects in these early graded B grafts foreshadowed a 20% occlusion rate at one year, this was significantly better (P < 0.05) than the late occlusion rate of 43% in grafts graded B because of trunk defects.

There are three types of distal (i.e., graft-coronary) anastomoses in this series: first, end-to-side anastomoses of single or some "Y" veins and a few internal mammary arteries; second and third, side-to-side and terminal end-to-side anastomoses associated with the SEQA veins noted earlier. Table 6 relates bypass patency grading early and after one year to the type of distal anastomosis. Although there appear to be significant differences between patency rates of end-to-side and side-to-side anastomoses generally, these do not achieve statistical significance with one interesting exception. The side-to-side anastomoses of SEQA veins had an 11% higher early (P < 0.01) and a 10% higher late (P < 0.05) patency rate, including 8% more early and 7% more late A grafts, than the end-to-side anastomoses of the same vein trunks. Grondin and Limet1 noted a similar phenomenon.

**Discussion**

We do not know a study comparable to this in scope or method and will not attempt to relate it to other reports on coronary bypass graft patency. The bias of accidentally selecting for follow-up patients with good or bad operative results has been excluded by examining, early after operation, every coronary bypass graft fashioned in a fairly large series of consecutive operations. Although all the original 1400 grafts have not been restudied at one year, 1132 have been examined and we have shown that this group is representative of the whole.

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**Table 5. Position of Defect as Determinant of Late Fate of Early Graded B Grafts**

<table>
<thead>
<tr>
<th>B grading determinant</th>
<th>Number of grafts with defect (%)</th>
<th>Late (1 year) grading of entire graft A (%)</th>
<th>B (%)</th>
<th>O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal anastomosis defect</td>
<td>3 (2.7)</td>
<td>0 (0)</td>
<td>3 (100)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Trunk defect</td>
<td>14 (12.5)</td>
<td>1 (7)</td>
<td>7 (50)</td>
<td>6 (43)</td>
</tr>
<tr>
<td>Distal anastomosis defect</td>
<td>91 (81.3)</td>
<td>38 (42)</td>
<td>33 (36)</td>
<td>20 (22)</td>
</tr>
<tr>
<td>Combined distal defect plus other defect(s)</td>
<td>4 (3.5)</td>
<td>2 (50)</td>
<td>1 (25)</td>
<td>1 (25)</td>
</tr>
</tbody>
</table>

*Relates to early and late study of 1132 grafts of which 112 were graded B at the early examination.

---

**Table 6. Graft Patency Related to Type of Distal Anastomosis**

<table>
<thead>
<tr>
<th>Type of anastomosis</th>
<th>Number</th>
<th>B</th>
<th>A (%)</th>
<th>B (%)</th>
<th>A + B (Patent) (%)</th>
<th>O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All grafts*</td>
<td>(E) 1132</td>
<td>891 (79)</td>
<td>112 (10)</td>
<td>1003 (89)</td>
<td>129 (11)</td>
<td></td>
</tr>
<tr>
<td>(L) 1132</td>
<td>842 (74)</td>
<td>77 (7)</td>
<td>919 (81)</td>
<td>213 (19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-to-side excluding all SEQA vein anastomoses†</td>
<td>(E) 883</td>
<td>694 (79)</td>
<td>88 (10)</td>
<td>782 (89)</td>
<td>101 (11)</td>
<td></td>
</tr>
<tr>
<td>(L) 883</td>
<td>662 (75)</td>
<td>57 (6)</td>
<td>719 (81)</td>
<td>164 (19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-to-side of SEQA veins</td>
<td>(E) 121</td>
<td>91 (75)</td>
<td>10 (8)</td>
<td>101 (83)</td>
<td>20 (17)</td>
<td></td>
</tr>
<tr>
<td>(L) 121</td>
<td>83 (69)</td>
<td>8 (7)</td>
<td>91 (75)</td>
<td>30 (25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side-to-side of SEQA veins</td>
<td>(E) 128</td>
<td>106 (83)</td>
<td>14 (11)</td>
<td>120 (94)</td>
<td>8 (6)</td>
<td></td>
</tr>
<tr>
<td>(L) 128</td>
<td>97 (76)</td>
<td>12 (9)</td>
<td>109 (85)</td>
<td>19 (15)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Relates to 1132 grafts studied early and one year postoperatively.
†Excludes 121 end-to-side and 128 side-to-side anastomoses of SEQA veins (single vein trunk with two or more coronary anastomoses).

Abbreviations: E = early postoperatively; L = late postoperatively.
The grading system described appears to have served a useful purpose. It will be evident, especially to those who habitually study coronary artery and coronary bypass angiograms, that our system embodies a definitely subjective element. We have tried to offset this by applying the rules fairly, a constant spur to our objectivity being the cogent requirement for assigning realistic employment-oriented medical categories to military personnel. Our early experiments in grading coronary bypass grafts included a C grade and also attempted to quantitate, separately, impairment of antegrade and retrograde flow from graft to artery; these failed because the system became not only impossibly cumbersome but also dishonest in the pretence of measuring the immeasurable. We believe that the data on the fate of grafts graded A or B in early studies confirm both the validity and the prognostic value of our grade assignments.

If patent coronary bypass grafts improve blood flow to ischemic muscle (it has been suggested that such flow need not be a mechanism of benefit from operation), we have demonstrated excellent early and late graft patency rates which should augur well for the patients. Furthermore, by graft grading, we have shown that most patent grafts in this series were of excellent quality. Some of the factors associated with early and late graft failure have been noted. A most important determinant of good results appears to be surgical skill in fashioning bypass coronary anastomoses.

Acknowledgment

We are very grateful to Miss Barbara Wills, of Statistics Canada, for advice and assistance in handling statistical data.

References


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**QT Interval Prolongation as Predictor of Sudden Death in Patients with Myocardial Infarction**

P. J. Schwartz, M.D., and Stewart Wolf, M.D.

**SUMMARY** Fifty-five patients with recent myocardial infarction and 55 healthy controls, matched for age, sex, race, height, weight, education and job, had an electrocardiogram taken every two months for seven years. Twenty-eight patients and one control had a sudden cardiac death. The QTc (mean of all values recorded) was found prolonged in one control (2%), five of 27 surviving patients (18%) and in 16 of 28 patients who had sudden death (57%). The difference between surviving and sudden death patients is significant (P < 0.01).

It is interesting that the only control with a long QT was the one who died suddenly of myocardial infarction. Among patients with previous myocardial infarction a prolonged QTc constitutes a 2.16 times greater risk for sudden death. We conclude that a constant prolongation of QTc in patients with myocardial infarction may help, with other risk factors, in defining a subgroup at higher risk for sudden death.

IN EARLIER STUDIES an imbalance in cardiac sympathetic innervation which prolongs the QT interval was shown to increase the arrhythmias associated with coronary artery occlusion and to lower the ventricular fibrillation threshold. The present study focuses on whether or not a prolonged QT corrected for rate (QTc) (> 440 msec), irrespective of its causes, is associated with sudden death in patients with myocardial infarction.

Our attention to the possibility that QT interval prolongation might be associated with increased risk of sudden death was brought about by clinical and experimental data. Congenital prolongation of QT interval (long QT syndrome) is associated with an extremely high incidence of ventricular fibrillation (VF) and sudden death. Drugs that prolong the QT interval (quinidine, amiodarone, tricyclic antidepressants and others) are also associated with sudden death due to VF. A vulnerability index has been proposed based on QT interval prolongation. In experimental animals manipulation of the sympathetic nervous system affects the QT interval. Maneuvers that lengthen it, such as ablation of the right stellate ganglion or stimulation of the left, increase the incidence of ventricular arrhythmias and of VF in anesthetized animals during myocardial ischemia as well as in conscious animals during physical or emotional stresses.

To test the prognostic significance of a consistently prolonged QT, a group of patients with previous myocardial infarction and their matched controls were followed for ten years, during the first four to seven years of which repeated ECGs were recorded every two months. Approximately half of the patient group and one of the controls died suddenly during the period of study. Among both patients and controls the QT measurements were correlated with the clinical outcome.

**Methods**

**Population Under Study**

There were 134 subjects in all, 67 patients and 67 healthy controls. The patients, 53 men and 14 women, had suffered a
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