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Comparison of costs of percutaneous transluminal coronary angioplasty and coronary bypass surgery for patients with angina pectoris

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To determine the costs of a procedure, the total costs of the department that provides the service must be considered and, in addition, the direct cost of the specific procedure. Applying this principle to the cost accounting of angioplasty and bypass surgery results in a direct, i.e. procedural, cost, including the initial hospital stay, of respectively 8694 Dfl and 20 987 Dfl. A review of the follow-up data for the first year after the original intervention revealed a 2% reintervention rate for bypass surgery, while this percentage was 29% for angioplasty. Adding the first year costs involved with reinterventions to the procedural costs results in a 1-year cost of angioplasty and bypass operation of 13 625 Dfl and 21 363 Dfl, respectively.

It is concluded that because of reinterventions in the first year, a mark up of 57% on the procedural cost of angioplasty must be added to cover 1-year costs, while for bypass surgery this is only 1%. Nevertheless, the 1-year cost for angioplasty is still 36% less than for bypass surgery. As reinterventions after PTCA may stay considerably higher than for CABG for several years, the mark-up percentages will be substantially higher for longer time spans. This may tend to equalize the total costs of PTCA and CABG over time spans of perhaps 5–8 years. Sufficient data are not available to verify this statement. Clinicians must realize that choosing the most appropriate procedure is not only a matter of medical assessment but also a matter of cost effectiveness. CABG can be seen as an 'investment decision' while PTCA tends to become a decision with characteristics of 'maintenance planning'!

Introduction

Percutaneous transluminal coronary angioplasty has become an alternative to coronary bypass grafting in an increasing number of patients. Technical advances with better steerable guidewires and lower-profile balloons together with more experienced operators have made more lesions accessible for PTCA. The initial percentage of patients suitable for angioplasty was originally estimated to be 10–20%[1]. Newer estimates vary between 25 and 50%[2]. Besides being an alternative for surgical revascularization, PTCA has also been advocated as a substitute for medical therapy[3] and has been investigated during the acute phase of myocardial infarction, alone or in combination with thrombolytic therapy[4–8], with varying results. Several authors have made a comparison between the costs of coronary angioplasty and of coronary bypass surgery[9–12]. Jang *et al.*[9] included only the direct procedure-related costs and found, assuming an 80% primary success rate, a cost reduction of 46% when a PTCA was carried out instead of a CABG. Kelly *et al.*[11] calculated 43% savings in 78 patients undergoing PTCA with a 74% success rate. In contrast with the previous authors, Reeder *et al.*[10] found only a 15% reduction in 1-year cost in unselected patients undergoing angioplasty, compared with surgically revascularized patients, while Black *et al.*[12] calculated 52% savings in patients undergoing angioplasty for multivessel disease. These figures are confusing, at least partially because comparisons are based on different costing concepts. Many publications are based on billed amounts i.e. tariffs. As is normal, bills have to represent costs. However, due to regulations, billing figures may differ considerably from costs, as will be discussed later.

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The purpose of our study was twofold. First of all we wanted to have a clear view of the full costs involved in each procedure based on normal business cost accounting procedures instead of billed amounts. For this purpose we had to allocate the total costs of the department of cardiology and cardiac surgery to specific procedures[13]. The second aim of our study was to calculate the initial and 1-year follow-up cost for 896 patients treated with angioplasty and to compare the amounts calculated with the 1-year cost of 1041 patients treated with bypass surgery. The costs of angiography and other diagnostic tests before the first intervention were not included, neither were the costs of individual medical treatment after the intervention, except for routine medication.

Data acquisition and patient selection

A: CALCULATION OF COSTS

The cost elements of a given cardiovascular procedure can be divided into direct and indirect costs. Direct costs can be attributed directly to a given procedure and include aids and appliances specifically used for this procedure. The indirect costs cannot be linked to specific procedures. Indirect costs include staff salaries, central supplies, fixed overheads, depreciation, interest and maintenance. To apply indirect costs to procedures, input–output coefficients (cost allocation ratios) are used characterizing the structure of production. To estimate the proportion of staff time and facility occupancy for different procedures in the catheterization laboratories, each common procedure was attributed a mean procedure time. Diagnostic left and right heart catheterization was scored as 1·0 standard procedure, as was pacemaker implantation. Cardiac biopsy as a single procedure and pacemaker battery replacement were scored as 0·5 standard procedure each, while angioplasty and valvuloplasty procedures were allocated 1·5 standard procedure time. Indirect costs for cardiac operations were apportioned on the basis that a standard bypass procedure, valve replacement, left ventricular aneurysmectomy and repairs of most congenital defects were counted as 1·0 standard procedure. Rethoracotomy was scored as 0·5 standard procedure, while heart transplantation and thoracic aorta aneurysmectomy were scored as 2·0 standard procedures.

The costs attributable to the departments of cardiology and cardiac surgery were collected from the hospital administration. The cost allocation ratios were based on investigations and interviews. Due to the mutual relations between different cost centres, the allocation of indirect costs is very time consuming when carried out manually. Therefore, the whole system has been computer implemented. All calculations were made for the year 1987.

Table 1 Clinical characteristics of CABG and PTCA patients

	CABG	PTCA
N	1041	896
Male (%)	88	90
Mean age (years)	53·0	53·0
Single vessel disease	192 (18%)	811 (91%)
Two or more vessel disease	849	85
EF ≤ 55%	31%	34%
EF ≥ 56%	69%	66%
Reintervention < 1 year	2%	29%

It should be noted that the term 'costs' can be understood in different ways. To stress this point, first of all, costs may differ from bills as pointed out earlier. Furthermore, when the term 'cost' is used in publications about cost comparisons with respect to PTCA/CABG, three cost concepts may be involved:

- direct costs, i.e. cost directly associated with the procedures;
- initial costs, i.e. direct costs plus the costs associated with initial care and immediate reinterventions;
- 1-year follow-up costs, i.e. all costs associated with a patient who underwent a specific procedure calculated over 1 year.

B: PATIENT SELECTION

1. Coronary bypass operation

The postoperative course of the first 1041 patients operated in the Thoraxcenter (between February 1971 and May 1980) has been previously reviewed[14]. The clinical characteristics of this group, as well as of the group who underwent angioplasty are given in Table 1. Of the operated group, 192 had single vessel disease, with 3% having reinterventions in the first postoperative year. The percentage of reinterventions in the whole group was 2%, and the costs of these reinterventions were added to the cost of CABG. As these data were collected before angioplasties were undertaken in the Thoraxcenter, all reinterventions were reoperations. On reviewing the films of the patients who had a reoperation, about half of them were considered in retrospect to be

candidates for angioplasty. So the costs of reinterventions in the operated group were equally attributed to reoperation and angioplasty treatment. Medical treatment after CABG at the Thoraxcenter includes the routine use of dipyridamole (Persantin®) and aspirin and the costs associated with these drugs were added to the cost of operation. Costs for rehabilitation were not included in this calculation. No data were available for other medical treatment or tests during the first year following operation, beyond those mentioned.

2. Coronary angioplasty

The first 896 patients who underwent angioplasty at the Thoraxcenter between September 1980 and November 1985 were reviewed for reinterventions within 1 year after the initial angioplasty. The total number of dilatation sessions for the same lesion in this group was 1017, with 93 patients undergoing a second dilatation and 14 two redilatations. The number of patients operated in this group within 1 year after the initial PTCA was 160 or 17·9%, with 86 patients having an operation on the same day and 74 patients at a later date. Of this latter group, 41 patients underwent a recatheterization between PTCA and CABG. The patients undergoing re-PTCA had their redilatation procedure during the same session directly after the diagnostic angiogram. For this reason no extra costs for recatheterization were calculated in this group. Medical treatment after PTCA consisted of aspirin for 6 months and the cost of this was added to the total 1-year cost of PTCA. As data for other medical treatment in the first year after bypass operation were not collected, costs for other medical treatment or tests within 1 year after angioplasty were also excluded.

Results

DIRECT COSTS OF PTCA, CABG AND MEDICAL TREATMENT

Applying a costing methodology normally used in business, angioplasty procedural costs were calculated for 1987, in which year 500 PTCA procedures were performed (Table 2). On average, 1·7 balloon catheters per procedure were used. Only low osmolar non-ionic contrast agents were employed. Costs of the operating theatre for bypass operation, 1 day postoperative care, 1 day on a surgical or cardiological ward and of a diagnostic heart catheterization can be calculated with the same costing model. The results are given in Table 3. The 1-year costs for medical treatment are also given in this Table. Combining the theatre costs of both interventions with postoperative costs, the duration of stay in hospital and of routine postoperative medication yields the figures in Table 4 and Fig. 1.

Without considering reinterventions in the first year, the cost of medical therapy is 13% of the cost of a bypass operation. PTCA is three times as expensive as medical treatment, while its direct costs are only 41% of the direct costs of bypass operation. The postoperative course as far as the number of reinterventions of the operated and

Table 2 Breakdown of procedural costs of angioplasty

Personnel			1517 Dfl*
medical	620		
nursing	305		
technical	331		
administrative	261		
Disposables		4176	
Medication and contrast			123
Maintenance			417
Interest and depreciation			931
Fixed overhead			300
Central supplies			179
Total procedure cost			7643

*Amounts in Dutch guilders. On 1 July 1987, one Dutch guilder was valued at 0·49 US dollar or 0·43 ECU.

Table 3 Calculated costs of common resources and procedures

Bypass operation (theatre costs)	9978 Dfl*
Postoperative I.C.U., per day	2614
Surgical ward, per day	653
Cardiology ward, per day	520
Diagnostic catheterization	3421
One year medical treatment	2770

*See Table 2 legend.

Table 4 One-year cost of medical treatment, bypass operation and angioplasty, excluding reinterventions

	Medical treatment	PTCA	CABG
Theatre	—	7643 Dfl*	9978
Ward	—	1040	10 452
Medication	2770	11	557
Total	2770	8694	20 987

*See Table 2 legend.

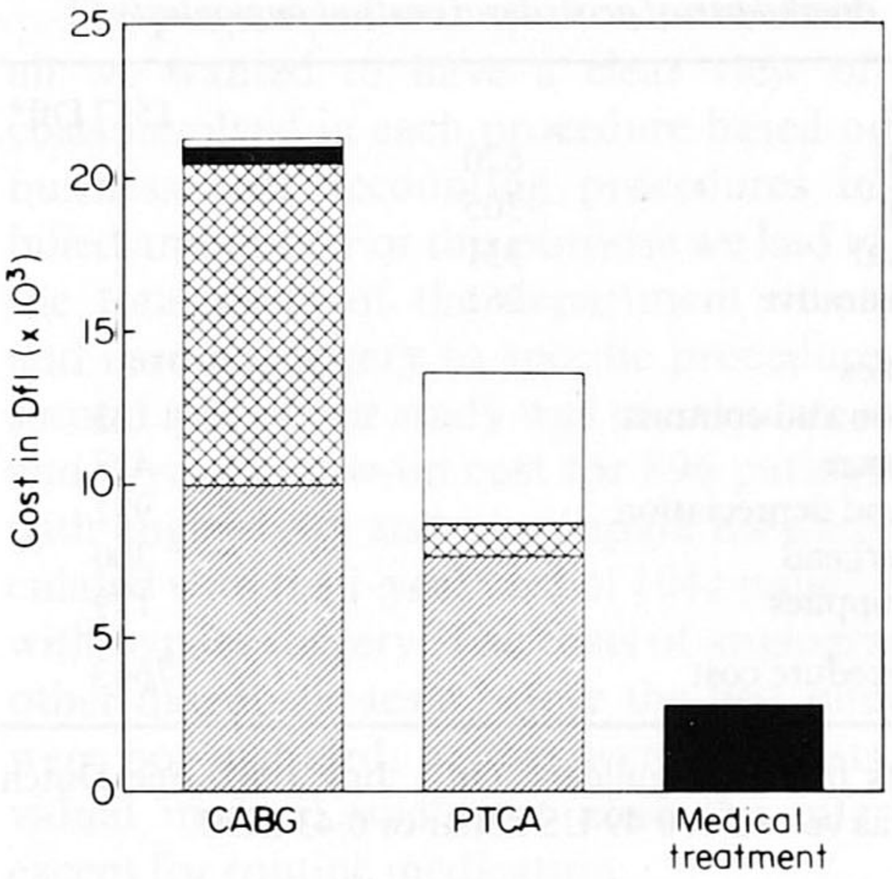

Figure 1 Proportional contribution of various cost factors to the total 1-year cost of bypass operation (CABG), angioplasty (PTCA) and medical treatment. Costs are given in thousands of guilders. In 1987 one Dutch guilder had an average value of 0·49 US dollar, or 0·43 ECU. □ = reinterventions, ▨ = theatre, ▩ = ward, ■ = medication.

dilated group is concerned, is given in Table 1. For the operated group the low number of 2% reinterventions was retrospectively equally divided between reoperation and angioplasty. As all these patients had a diagnostic angiogram before reintervention, the total 1-year costs of bypass operation must be increased by 2% of the costs of a diagnostic catheterization, 1% of the costs of bypass operation and 1% of the costs of angioplasty. As diagnostic catheterization includes, in addition to the theatre costs, 1 day on a cardiological ward, total costs for one diagnostic catheterization is 3971 Dfl (Table 3). Costs of one bypass operation after adjustment for 1-year follow-up reinterventions amounts to 21 363 Dfl (Table 5). To compute the costs of angioplasty including 1-year follow-up, 17·9% of the costs of bypass operation, 11·4% of the costs of angioplasty and 4·6% of the costs of a diagnostic catheterization must be added to the direct procedure costs. Costs of angioplasty including 1-year follow-up reinterventions and routine medication amounts to 13 625 Dfl. The initial cost ratio of treating a patient with medical therapy, angioplasty or with bypass operation has changed from 13:41:100 after adjustment for 1-year follow-up costs to 13:64:100. Nevertheless, the savings per year per patient are with medical treatment 18 593 Dfl and with angioplasty 7738 Dfl, compared with bypass operation.

Table 5 All inclusive costs of medical treatment, angioplasty and bypass operation including reinterventions in the first postoperative year

	Medical treatment	PTCA	CABG
Direct costs	2770 Dfl*	8694	20 987
Diagnostic catheterization		183	79
(re) CABG		3757	210
(re) PTCA		991	87
Total	2770	13 625	21 363

*See Table 2 legend.

Discussion

One limitation of our comparative study is the overwhelming preponderance of single vessel disease patients in the angioplasty group compared with the surgical group. On theoretical grounds, it can be calculated that with a primary success rate per lesion of 95% and a restenosis rate per lesion of 30%, only 29·4% of all patients with three vessel dilatation will have all vessels patent without restenosis at follow-up angiography ((0·95 × 0·95 × 0·95) × (0·7 × 0·7 × 0·7) × 100). This could mean, on theoretical grounds, a reintervention in 65·6% of the original patient population with consequent much higher 1-year costs for angioplasty. However, several authors[12,15–21] have reported much lower clinical recurrences necessitating reinterventions. The percentage of patients in need of a second intervention, coronary bypass operation or angioplasty, varied in these reports between 20·5 and 39%. However, the reports do not always make clear whether patients without a successful dilatation were all surgical candidates and were subsequently operated on. In our series, all patients with an unsuccessful angioplasty were operated. This explains the high percentage of patients operated on the day of the angioplasty attempt (9·6%), and reflects merely the overall percentage of angioplasty failure in this group of patients. As these data were collected partly before steerable dilating systems became available, this percentage is not surprising. If on the other hand, patients with a failed angioplasty attempt are not candidates for bypass operation, but for medical treatment, cost comparison should be made between angioplasty and medical treatment, a comparison which is highly unfavourable for angioplasty.

Another limitation of our study is that the follow-up costs, in terms of medication, follow-up outpatient clinic visits, and non-invasive cardiological tests in the first postintervention year were not taken into account. One might speculate that these costs could be higher in the angioplasty group, because they had more reinterventions, as a result of more frequent recurrence of anginal complaints in the first postoperative year. It can be expected from these data that angioplasty patients have more frequent outpatient clinic visits, more extensive medication and more exercise tests during one year follow-up. Using the same costing model, adjusting for one extra outpatient clinic visit, 2 months of triple therapy and one exercise test, for each patient with recurrent symptoms, the 1-year costs of angioplasty would be increased by 210 Dfl and the 1-year costs of surgery by 19 Dfl per patient. Adjusting for these speculative costs, the 1-year cost ratio for PTCA vs CABG, which was originally 63·8%, becomes 64·8%, a comparatively small change.

We also tried to compare the absolute costs involved in both procedures with data reported in the literature. Two problems arise in this comparison. First, we do not have data for costs in other European centres and, second, the reported costs in the literature are normally calculated using billing amounts. Both factors may contribute substantially to different cost levels. Direct costs of both procedures were collected by Jang in 1984[9] and averaged 15 580 USD for CABG and 5315 USD for PTCA, with a large variation in costs reported by the various hospitals. These costs in our hospital were respectively 9444 USD and 3912 USD. Including 1-year reinterventions, Kelly *et al.*[11] calculated a 1-year cost of 18 559 USD and 7689 USD for bypass operation and angioplasty, respectively. Reeder *et al.*[10] calculated a much higher cost for angioplasty (11 472 USD), including 1-year follow-up, but the costs for bypass operation, including 1-year postoperative costs were lower (13 387 USD). Recently, a cost comparison was made in 100 patients undergoing angioplasty or bypass operation for multivessel disease. One-year costs were, respectively, 11 100 USD and 22 862 USD[12]. The overall cost level, based on hospital and physician charges for both procedures, is higher in the United States than the calculated cost level at the Thoraxcenter. Part of this difference is due to the special status of University hospitals in the Netherlands, where physicians do not charge their patients, but are paid by the government.

Billing levels in our hospital for routine angioplasty and bypass operation are respectively 2364 USD and 12 728 USD, varying in opposite directions from the calculated costs. These differences are due to governmental regulations, who set the billing levels for most medical procedures. However, the cost ratio angioplasty vs bypass operation, including 1-year reinterventions, is comparable since this ratio in the three above-mentioned studies was 0·57, 0·86 and 0·48, while in our study it was 0·64.

Medical therapy is much less expensive in the first year than either angioplasty or bypass operation, the cost ratio being respectively 0·20 and 0·13, assuming full antianginal medical therapy. Although this difference in cost is large in the first year, the real difference can only be appreciated if we know the number of patients having an intervention after 1-year of medical therapy, and how many patients from the invasive therapy group go on to have further reinterventions and/or medical therapy after the first year. If all medical therapy patients continue on medical therapy and no further reinterventions occur in the invasive group after 1 year, the break-even point for angioplasty would be 6 years and for bypass operation 11·5 years, assuming a 7% interest rate. This means, with the above-mentioned assumption, that the costs of 6 years of medical therapy are the same as those of one angioplasty procedure, and the costs of 11·5 years of medical therapy are the same as those of one coronary bypass operation.

As angioplasty is a relative new procedure compared with bypass surgery, technical developments making more lesions accessible for angioplasty are continuously taking place. This development might increase the primary success rate of the procedure and diminish overall procedural costs. On the other hand, costs of more sophisticated balloon systems tend to be higher, offsetting the cost reduction caused by the higher initial success rate.

Reduction of angioplasty costs can be achieved by several means. First of all, direct procedural costs can be reduced by performing a higher number of cases with the same number of staff members and with the same catheterization facilities. In our situation, all catheterization laboratories were fully occupied with diagnostic and interventional procedures. So increasing the number of procedures would imply extra personnel with consequently the same (or higher) costs per procedure for personnel, because pay for overtime is higher. In this situation there might be a reduction in fixed overhead, interest and depreciation costs,

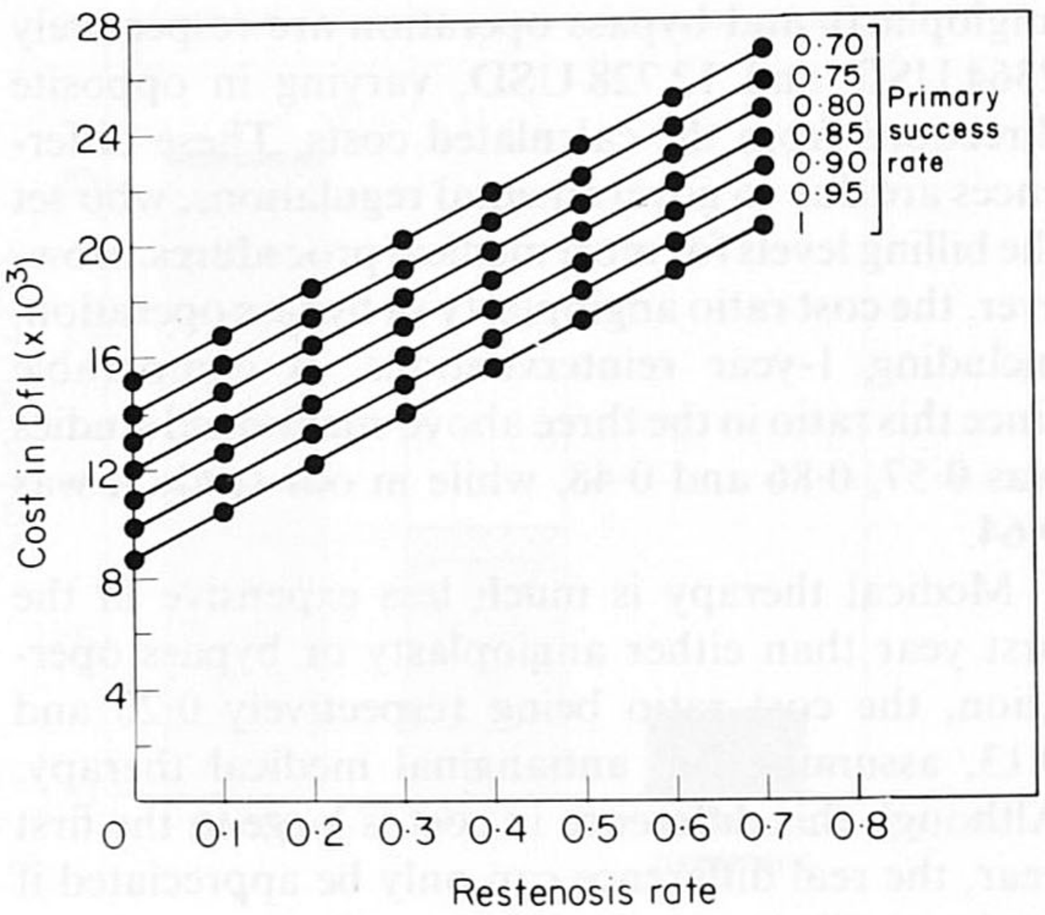

Figure 2 One year cost of angioplasty (PTCA) at varying primary success and restenosis rates, assuming that all primary failures undergo bypass operation (CABG), and all patients with restenosis have a reintervention, i.e. 50% re-PTCA and 50% CABG. Costs are given in thousands of guilders for primary success percentages varying from 70 to 100, and for restenosis percentages varying from 0 to 70.

although maintenance costs would be higher with a higher workload per laboratory.

A reduction in costs could also be achieved by using less and cheaper disposables. Until now there has been no proof that a gradual dilatation with balloons of increasing diameter gives better early and longterm results than employing directly a balloon size that dilates the stenotic part to its original size.

The second target for cost reduction is the inpatient stay after the procedure. We have reduced this time gradually in the past 8 years to 36 h. We feel that, unless smaller guiding catheters become available, a 24–36 h postoperative inpatient stay is a minimal requirement.

The third and most important course of action for cost reduction is the prevention of surgery and restenosis. Performing only straightforward cases, as originally indicated by Grüntzig[22], will increase the primary success rate, and lower the costs. This would result in a higher number of patients being referred primarily for surgery. It can be calculated from the data given that even with a failure rate of angioplasty of as high as 25%, and a restenosis rate of 50%, costs of both procedures are at the same level (Fig. 2). These extreme conditions have never been published, which means that doing relatively simple procedures might reduce the cost per procedure, but performing complicated cases with a high initial failure rate and a high subsequent restenosis rate is still cheaper than surgery.

A major reduction in the costs of the angioplasty procedure can only be achieved by solving the problem of restenosis. In our situation, 57% must be added to the direct procedural costs of angioplasty, to cover first year expenses, merely because of reinterventions. So far no pharmacological regimens post angioplasty have reduced the incidence of restenosis. Newer techniques, such as catheter atherectomy, rotating abrasion, laser balloon angioplasty, and stent implantation, might have an influence on the rate of restenosis. However, they will increase the cost of angioplasty procedures and the total net result will depend on the number of restenoses prevented.

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