Hospital Resource Utilization for Primary and Revision Total Hip Arthroplasty

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Background: Previous reports have suggested that hospital resource utilization for revision total hip arthroplasty is substantially higher than that for primary total hip arthroplasty. However, current United States Medicare hospital-reimbursement policy does not distinguish between the two procedures. The purpose of this study was to compare primary and revision total hip arthroplasties with regard to actual hospital resource utilization and to identify clinical and demographic factors that are predictive of higher resource utilization associated with these procedures.

Methods: We evaluated the clinical, demographic, and economic data associated with 491 consecutive unilateral primary or revision total hip arthroplasties performed by two surgeons at a single institution between January 2000 and December 2002. The distributions of various demographic, clinical, and utilization characteristics were compared between the two types of arthroplasty procedures, and multivariable linear regression techniques were used to determine independent patient characteristics that were predictive of higher costs for both the primary and the revision procedures.

Results: The mean total hospital cost was $31,341 for the revision procedures compared with $24,170 for the primary procedures ($p < 0.0001$). The mean operative time was 41% longer for the revisions than for the primary procedures (4.5 hours compared with 3.2 hours, $p < 0.0001$), the mean estimated blood loss was 160% higher (1348 mL compared with 518 mL, $p < 0.0001$), the mean complication rate was 32% higher (29% compared with 22%, $p = 0.072$), and the mean length of the hospital stay was 16% longer (6.5 days compared with 5.6 days, $p = 0.0005$). A higher severity-of-illness score (a measure of preoperative medical health) was predictive of higher resource utilization for both primary and revision arthroplasty even after adjustment for other factors. Preoperative femoral and acetabular bone loss and a diagnosis of periprosthetic fracture were predictive of higher resource utilization associated with revision procedures.

Conclusions: At one institution, hospital resource utilization for revision total hip arthroplasty was found to be significantly higher than that for primary arthroplasty. This information is not reflected by current United States Medicare hospital reimbursement, which is the same for all lower-extremity arthroplasty procedures, regardless of the diagnosis, the complexity of the procedure, or the patient's baseline medical health. If these findings are generalizable to other institutions, appropriate reimbursement formulas should be developed to accurately reflect the true costs of caring for patients with a failed total hip arthroplasty.

Level of Evidence: Economic and decision analysis, Level I. See Instructions to Authors for a complete description of levels of evidence.

Despite the excellent results that have been reported following primary total hip arthroplasty, factors related to implant longevity and an increase in the number of procedures performed in younger, more active patients have led to an increase in the volume of revision total hip arthroplasties performed in the United States over the past decade. The American Academy of Orthopaedic Surgeons (AAOS) has estimated that the number of revision total hip arthroplasties will continue to rise at a rate of 20% to 30% per year over the next three decades[1].

Previous cost-identification studies of total hip arthroplasty have suggested that hospital resource utilization for revisions is substantially higher than that for primary procedures[2-7]. However, this information is not reflected by Medi-

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care hospital reimbursement, which is the primary payer for >60% of all primary and revision total hip arthroplasties that are performed in the United States[8]. Currently, Medicare reimbursement is the same for all lower-extremity arthroplasty procedures under Diagnosis Related Group (DRG) 209, regardless of the diagnosis, the complexity of the procedure, or the patient's health status at admission. This policy is distinctly different from Medicare reimbursement policies for other surgical procedures, including spinal fusion and coronary artery bypass grafting, which have been modified in recent years to account for differences in patient characteristics and the complexity and resource intensity of these procedures[9,10]. The discrepancy between resource utilization and Medicare reimbursement for revision total hip arthroplasties has resulted in substantial financial losses for hospitals that perform these procedures[5] and could ultimately jeopardize patient access to care as hospitals attempt to limit ongoing losses.

Previous reports on this subject have not dealt with the relationship between patient demographics and clinical characteristics and the costs associated with primary and revision total hip arthroplasties. Certain baseline patient characteristics, including age, body mass index, diagnosis, medical comorbidities, and severity of bone loss, could be predictive of hospital resource utilization; therefore, it could be useful to incorporate these characteristics into a modified prospective hospital reimbursement system for total hip arthroplasties.

The specific aims of this study were to compare hospital resource utilization between primary and revision total hip arthroplasties and to identify baseline clinical and demographic factors that are predictive of higher use of resources for primary and revision total hip arthroplasties. We tested two hypotheses: (1) hospital resource utilization for revision total hip arthroplasty is significantly higher than that for primary total hip arthroplasty, and (2) patient age, gender, diagnosis, baseline medical health, and magnitude of bone loss influence resource utilization and the total cost of care associated with total hip arthroplasty.

Materials and Methods

We employed a retrospective cost-identification cohort design to collect and analyze clinical, demographic, and economic data associated with 491 consecutive unilateral primary or revision total hip arthroplasties performed at a single institution by two surgeons between January 1, 2000, and December 31, 2002. Total hip arthroplasty was defined by four CPT (current procedural terminology) codes: 27130 (primary total hip arthroplasty), 27137 (revision of the acetabular component only, with or without autograft or allograft), 27138 (revision of the femoral component only, with or without autograft or allograft), and 27134 (two-component revision, with or without autograft or allograft)[11]. Preoperative clinical and demographic data, including age, height, weight, All-Patient Refined Diagnosis-Related Group Severity of Illness (APR-DRG SOI), payer class, diagnosis, and presence of femoral and acetabular osseous deficiencies[12,13], were obtained from a review of the radiographs and the hospital medical record. All-Patient DRGs (AP-DRGs) are an expansion of the basic DRGs and are intended to be more descriptive of both Medicare and non-Medicare populations. All-Patient Refined DRGs (APR-DRGs) incorporate severity-of-illness subclasses into AP-DRGs. The APR-DRG Severity of Illness (SOI) is a weighted index that is intended to reflect a patient's baseline medical health and ranges from 1 (lowest severity of illness) to 4 (highest severity of illness)[14]. Clinical outcome data, including estimated blood loss, use of autogenous and allogenic bone graft, and complications that occurred during the hospital stay were obtained from the hospital medical record. Data on resource utilization, including operative time, length of hospital stay, discharge disposition, and hospital costs by cost center, were extracted from the hospital administrative decision support database (TSI, Eclipsys, Brighton, Massachusetts). This database contains detailed hospital cost data based on actual resource utilization rather than charges or cost-to-charge ratios. The study was approved by our institution's committee on human research.

Statistical Analysis

Preoperative clinical and demographic characteristics were compared between primary and revision total hip arthroplasties, and significant differences were ascertained with use of independent-samples t tests, chi-square statistics, and Fisher exact tests as appropriate. Clinical and economic outcome variables were compared in the same manner.

To avoid the skewed nature of cost data, mean total costs were recoded so that the values for six outlier subjects (with values greater than three standard deviations above the mean) were reassigned to three standard deviations above the mean, according to the method of Katz et al.[15]. To further ensure that any departures from normality in the cost data were not substantially affecting the p values derived with the significance tests, we also performed all tests on the log of costs, as this transformation is often used to yield a more normal distribution[16].

Hospital costs were aggregated into eleven distinct cost centers, and the centers were ranked by the proportion of resources used for both primary and revision total hip arthroplasty. To adjust for temporal changes in costs, all economic data were inflated to 2003 prices by using the medical care component of the Consumer Price Index[17]. Independent-samples t tests were used to compare mean total costs by cost center and in aggregate for primary and revision total hip arthroplasties.

Multivariable linear regression techniques were used to evaluate relationships between patient clinical and demographic characteristics and total costs per patient. The patient and procedural characteristics were age (less than sixty-five years old or sixty-five years old and over); gender; body mass index (<30 or ≥30); APR-DRG SOI score (dichotomized to SOI 1 or 2 [reference] or SOI 3 or 4, in order to avoid statistical instability due to sparse cells at the low and high ends of this measure); diagnoses associated with the primary procedures (with osteoarthritis being the reference diagnosis and developmental hip dysplasia, osteonecrosis, and inflammatory arthritis being adjusted for) and diagnoses associated with the

TABLE I Baseline Clinical and Demographic Characteristics Associated with Primary and Revision Total Hip Arthroplasties (N = 491)*

Characteristic	Primary Arthroplasty (N = 248)	Revision Arthroplasty (N = 243)	P Value
Male	123 (50)	109 (45)	0.29†
Age *(yr)* at op.‡	58.4 ± 15.2	61.3 ± 15.3	0.036§
Body mass index‡	28.6 ± 6.7	27.3 ± 6.5	0.031§
Severity-of-Illness (SOI) score			<0.0001#
1	127 (51)	3 (1)	
2	99 (40)	138 (58)	
3	18 (7)	94 (39)	
4	4 (2)	4 (2)	
Payer class			<0.0001†
Medicare (traditional)	78 (31)	121 (50)	
Other	170 (69)	122 (50)	
Diagnosis leading to primary procedure			
Osteoarthritis	192 (77)	—	
Osteonecrosis	38 (15)	—	
Developmental hip dysplasia	10 (4)	—	
Inflammatory arthritis	5 (2)	—	
Acute femoral neck fracture	3 (1)	—	
Mode of failure leading to revision**			
Periprosthetic fracture	—	12 (5)	
Mechanical loosening	—	88 (36)	
Osteolysis	—	95 (39)	
Infection	—	35 (14)	
Implant failure	—	10 (4)	
Recurrent dislocation	—	55 (23)	
Acetabular deficiency	59 (24)	180 (74)	<0.0001†
Femoral deficiency	8 (3)	137 (56)	<0.0001†

*The values are given as the number with the percentage in parentheses unless otherwise indicated. †Chi square test. ‡The values are given as the mean and standard deviation. §Independent samples t test. #Fisher exact test. **More than one mode of failure may have been present in each patient.

revisions (with osteolysis being the reference diagnosis and periprosthetic fracture, mechanical loosening, implant failure, infection, and recurrent dislocation being adjusted for); and femoral and acetabular bone deficiencies (as assessed with the AAOS classification of femoral and acetabular osseous abnormalities associated with total hip arthroplasty[12,13]).

All analyses were performed with use of SAS software, version 8.2 (Cary, North Carolina), for Microsoft Windows.

Results

Baseline Demographic, Clinical, and Economic Outcomes

Baseline demographic and clinical variables of the cohorts treated with the primary and revision total hip arthroplasties are presented in Table I. The mean age (and standard deviation) was 61.3 ± 15.3 years at the time of the revision total hip arthroplasties and 58.4 ± 15.2 years at the time of the primary total hip arthroplasties ($p = 0.036$). The mean body-mass index of the patients treated with revision (27.3 ± 6.5) was slightly lower than that for the patients treated with primary arthroplasty (28.6 ± 6.7) ($p = 0.031$). The patients treated with revision were more likely than those treated with primary arthroplasty to have more serious associated medical comorbidities, as evidenced by a higher APR-DRG SOI score ($p < 0.0001$). Fifty percent of the patients treated with revision total hip arthroplasty were covered by traditional Medicare plans compared with 31% of those treated with primary total hip arthroplasty ($p < 0.0001$). Almost three-quarters of the revision procedures were performed on patients with acetabular bone deficiencies, whereas slightly less than a quarter of the patients treated with a primary procedure had acetabular bone loss ($p < 0.0001$). More than half of the patients treated with a revision had femoral bone loss, compared with only 3% of the patients treated with a primary procedure ($p < 0.0001$).

Clinical and Economic Outcomes

Clinical and economic outcomes for both cohorts are presented in Table II. The mean estimated blood loss was 1348 ± 1146 mL in association with the revisions and 518 ± 290 mL in association with the primary total hip arthroplasties ($p < 0.0001$). The mean operative time was 4.5 ± 1.3 hours for the revisions and 3.2 ± 0.8 hours for the primary arthroplasties ($p < 0.0001$), a difference of >40%. The patients treated with a revision were more likely than those treated with a primary procedure to have a complication during their hospital stay, with complication rates of 29% and 22%, respectively ($p = 0.072$). When the complication rates were compared according to type, the most striking difference between the cohorts was associated with infections: only 2% of the primary total hip arthroplasties were complicated by infection, compared with 7% of the revision total hip arthroplasties ($p = 0.003$).

As expected, the use of autogenous and allogeneic bone grafts differed dramatically between the two procedures. Autogenous structural bone grafts were used in 3% of the primary total hip arthroplasties (all of which were performed because of developmental dysplasia) and in none of the revision procedures. Morselized autogenous bone was used in 12% of the primary total hip arthroplasties and in no revision procedure. Of the allogenic bone grafts that were used in the revision procedures, 56% were morselized, 23% were structural, and 21% were onlay cortical struts. Only two primary

TABLE II Clinical and Economic Outcomes Following Primary and Revision Total Hip Arthroplasties* (N = 491)

Characteristic	Primary Arthroplasty (N = 248)	Revision Arthroplasty (N = 243)	P Value
Estimated blood loss† *(mL)*	518 ± 290	1348 ± 1146	<0.0001‡
Operative time† *(hr)*	3.2 ± 0.8	4.5 ± 1.3	<0.0001‡
Complications during hospital stay			
Bleeding	6 (2)	14 (6)	0.061§
Cardiac	14 (6)	19 (8)	0.34§
Mental	11 (4)	9 (4)	0.68§
Thromboembolic	5 (2)	2 (1)	0.45#
Pulmonary	0 (0)	3 (1)	0.12#
Postop. ileus	4 (2)	3 (<1)	1.00#
Infection	4 (2)	17 (7)	0.003§
Other	30 (12)	38 (16)	0.26§
Any complication	54 (22)	70 (29)	0.072§
Autogenous bone graft (primary only)			
Structural	8 (3)	—	
Morselized	30 (12)	—	
Allogenic bone graft			
Structural	1 (<1)	55 (23)	
Morselized	—	136 (56)	
Onlay cortical strut	1 (<1)	51 (21)	
Discharge disposition			0.015§
Home (routine)	71 (29)	47 (19)	
Skilled nursing facility	59 (24)	84 (35)	
Home health	109 (44)	99 (41)	
Other	9 (4)	13 (5)	
Length of hospital stay† *(days)*	5.6 ± 2.1	6.5 ± 3.6	0.0005‡
Total costs†** *($)*	24,170 ± 6703	31,341 ± 11,989	<0.0001‡
Readmissions within 90 days after op.			
0	223 (94)	219 (90)	0.050#
1	15 (6)	20 (8)	
2	0 (0)	2 (<1)	
3	0 (0)	2 (<1)	

*The values are given as the number with the percentage in parentheses unless otherwise indicated. †The values are given as the mean and standard deviation. ‡Independent samples t test. §Chi-square test. #Fisher exact test. **Cost figures are given in 2003 U.S. dollars; outliers were recoded to three standard deviations above the mean.

TABLE III Costs* Aggregated by Cost Center for Primary and Revision Total Hip Arthroplasties (N = 490)

	Primary (N = 248)		Revision (N = 242)†		
Cost Center	% of Total†	Mean and Stand. Dev.	% of Total†	Mean and Stand. Dev.	P value§
Op. room equipment and implants	35.9	8940 ± 2817	38.9	12,620 ± 6938	<0.0001
Nursing/accommodation	17.6	4394 ± 2525	16.7	5416 ± 4163	0.0005
Op. room time and staff	13.7	3401 ± 1404	14.0	4529 ± 1965	<0.0001
Material services	11.1	2757 ± 1338	7.3	2359 ± 1428	0.0001
Anesthesia/postanesthesia care unit	6.3	1573 ± 986	5.5	1768 ± 834	0.0006
Rehabilitation	4.7	1173 ± 437	3.4	1101 ± 606	0.020
Blood products	4.2	1057 ± 2983	5.1	1668 ± 2489	0.0009
Pharmacy	3.5	869 ± 1947	4.5	1466 ± 7076	0.0001
Radiology	1.7	414 ± 529	1.5	478 ± 538	0.005
Laboratory	0.9	225 ± 387	2.0	655 ± 464	<0.0001
Ancillary services	0.4	112 ± 595	1.1	365 ± 1424	0.001

*Cost figures are given in 2003 U.S. dollars. †Cost data were not available for one revision total hip arthroplasty. ‡The percentage of the total average cost for the total hip arthroplasty. §Independent samples t test on logged costs.

procedures were performed with any type of allograft.

The patients treated with revision total hip arthroplasty were more likely to be discharged to an acute or subacute-care facility than were those treated with primary arthroplasty ($p = 0.015$). The average length of the hospital stay was 6.5 ± 3.6 days for the revisions and 5.6 ± 2.1 days for the primary total hip arthroplasties ($p = 0.0005$). The mean hospital cost was $31,341 ± $11,989 for the revisions and $24,170 ± $6703 for the primary arthroplasties, a difference of 30% ($p < 0.0001$). The revision procedures were more likely than the primary procedures to result in one or more readmissions within ninety days after the surgery ($p = 0.050$).

The mean costs aggregated by cost center for the primary and revision total hip arthroplasties are shown in Table III. The mean costs associated with nine of the eleven cost centers were higher for the revisions than they were for the primary arthroplasties. Costs incurred in the operating room accounted for ≥50% of the total costs in both cohorts.

Multivariable Regression Analysis

After we controlled for all independent variables (age, gender, body mass index, APR-DRG SOI score, diagnosis, and the presence of femoral and/or acetabular bone deficiencies), the only variable that was associated with higher resource utilization for the primary total hip arthroplasties was an APR-DRG SOI rating of 3 or 4, which was associated with a cost increase of $5250 ($p = 0.0006$) (see Appendix). A higher APR-DRG SOI rating (SOI 3 or 4), a diagnosis of periprosthetic fracture, and the presence of acetabular and femoral bone deficiencies were all associated with higher resource utilization for the revision total hip arthroplasties, with cost increases of $5502 ($p = 0.0002$), $11,794 ($p = 0.0019$), $4440 ($p = 0.0071$), and $8016 ($p < 0.0001$), respectively (see Appendix).

Discussion

Several previous investigators have attempted to quantify and compare the costs associated with primary and revision total hip arthroplasties[2,5-7]. Many of these studies were limited by small sample sizes and/or limited access to appropriate and accurate hospital-resource-utilization data. Several investigators used hospital charge data or cost-to-charge ratios to estimate costs[2-4,6,7,18]. As noted by Katz et al.[15] and by Finkler[19], billed charges are an imprecise measure of both costs and resource utilization for a variety of reasons, the most important of which is the fact that the economic basis of charges differs substantially among health care facilities and geographic locations. The economic data used in our study were obtained from a hospital activity-based costing software package (TSI Eclipsys) that provides a much more detailed and accurate representation of actual hospital resource utilization than do charges or cost-to-charge ratios.

We found that, compared with patients treated with primary total hip arthroplasty, patients treated with revision total hip arthroplasty were older, had more baseline medical comorbidities, and were more likely to have radiographic evidence of acetabular and femoral bone loss (Table I). Furthermore, our data demonstrated that revision total hip arthroplasties are associated with a longer length of hospital stay, longer operative time, greater use of femoral and acetabular allograft bone, higher complication rates, a higher likelihood of discharge to a subacute-care facility, and significantly higher hospital costs (Table II).

We found that a major portion (≥50%) of the total costs associated with both primary and revision total hip arthroplasties were incurred in the operating room (Table III), an observation that was similar to those in previous reports[5,18,20,21]. This finding underscores the need for hospitals, surgeons,

payers, and implant manufacturers to work together to control costs associated with orthopaedic implants.

To our knowledge, we are the first to attempt to identify specific patient characteristics that can be recognized preoperatively and are predictive of higher resource utilization associated with primary and revision total hip arthroplasties. The ability to identify such patient characteristics is important if one is to recommend changes to a prospective reimbursement system such as the Medicare DRG system.

We found the APR-DRG Severity of Illness (SOI) score to be a useful predictor of resource utilization for both primary and revision total hip arthroplasties after we had controlled for other relevant clinical and demographic variables. This observation suggests that a higher intensity of resources are used in the treatment of patients with substantial medical comorbidities during the period of hospitalization following total hip arthroplasty. We also found that both femoral and acetabular bone deficiencies were associated with higher resource utilization for revision total hip arthroplasties. Interestingly, bone deficiencies were not predictive of higher resource use for primary total hip arthroplasties. This is because, in most cases, autologous bone graft was used to reconstruct both femoral and acetabular deficiencies during primary total hip arthroplasties, whereas bone deficiencies associated with revision total hip arthroplasties necessitated the use of both morselized and structural allograft bone for reconstruction (Table II). These findings agree with those of Crowe et al., who reported substantially higher costs associated with the use of femoral bone graft and a trend toward higher costs associated with the use of acetabular bone graft in revision total hip arthroplasty[7]. Additionally, we found that a diagnosis of periprosthetic fracture was predictive of higher resource utilization associated with revision total hip arthroplasties, even after we had controlled for all other patient characteristics, including the APR-DRG SOI score. This could be due to the urgent nature of treating patients with a periprosthetic fracture, many of whom require an extensive inpatient preoperative workup. In contrast, patients with other diagnoses who require revision total hip arthroplasty are usually treated electively after appropriate outpatient preoperative medical evaluation has been completed.

Currently, Medicare reimbursement for all lower-extremity arthroplasties is the same under DRG 209. The original rationale behind grouping patients into DRGs for reimbursement purposes was that specific DRGs would have common demographic, diagnostic, and therapeutic attributes that would determine their level of resource intensity[14]. The original DRG codes that were adopted in the early 1980s were developed on the basis of statistical algorithms applied to hospital billing data to formulate patient groups that were similar in resource intensity. However, as noted by 3M Health Information Systems, the developer of the APR-DRG system that is commonly used for the non-Medicare patient population, patients within a single DRG are clinically diverse[14]. Therefore, the authors of this system recommended that all available patient characteristics that would be expected to affect resource intensity consistently be incorporated into a DRG. Furthermore, their research has shown that certain complications and comorbidities have a greater impact on hospital resource use than others. Our findings agree with the recommendations of the 3M group and suggest that modifying DRG 209 to account for differences in certain patient characteristics, including diagnosis, a measure of preoperative medical health, and the presence of bone deficiencies, would allow Medicare and other payers to more accurately match hospital reimbursement to resource intensity associated with total hip arthroplasties.

Our study had several notable limitations. First, our analysis focused only on the direct medical costs associated with the initial period of hospitalization. Second, the study was undertaken from a hospital perspective rather than a societal perspective. Certainly there are other direct and indirect, nonmedical costs incurred by both patients and society related to primary and revision total hip arthroplasties. However, since DRGs are intended to match reimbursement to resource utilization during the inpatient hospitalization, we chose to focus our analysis on hospital resource utilization only. Finally, our analysis was limited to two surgeons from a single institution in a single geographic location. The benefit of using data from a single institution is the ability to obtain detailed, patient-specific cost and clinical data, including cause of revision, presence of femoral and acetabular bone loss, operative time, estimated blood loss, and length of the stay in the hospital. However, limiting the analysis to data from a single institution potentially limits the generalizability of the results. Nevertheless, our sample size was large, and the relative differences in resource utilization between primary and revision total hip arthroplasties were similar to those reported in other studies in which billed charges and other measures of resource utilization were used[2,4,6,7]. Furthermore, the distribution of diagnoses and causes of the revisions were similar to those reported in other large series of primary and revision total hip arthroplasties[22,23]. Therefore, we are confident that, although the absolute costs may be specific to our institution, our findings regarding the differences in resource utilization between primary and revision total hip arthroplasties are generalizable to the larger population. We agree that additional studies should include data from other institutions in order to determine whether these patterns of resource utilization are consistent in other regions of the country.

Hospitals often incur substantial financial losses associated with revision total hip arthroplasties, and these losses are beginning to have a substantial impact on the overall financial viability of institutions that perform high volumes of revision total hip arthroplasties[2,4,5,21,24]. Furthermore, financial losses incurred from revision total hip arthroplasties continue to contribute to already mounting financial losses at large academic medical centers, where the majority of these procedures are performed[9,25], potentially compromising the ability of these centers to accomplish their important social goals[26]. Because of the economic consequences to the institution, several high-volume academic medical centers have already begun consid-

ering limiting referrals of patients with failed total hip replacements who are in need of revision surgery[27]. If these trends continue, access to care for patients with a failed total hip arthroplasty could be jeopardized and, as a result, patient outcomes could begin to suffer. In order to address this important problem, hospitals, surgeons, and payers should work together to develop a more equitable hospital reimbursement system based on well-defined patient characteristics that are associated with higher resource utilization related to primary and revision total hip arthroplasties.

Appendix

eA Tables presenting the results of multiple regression analyses of the predictors of total costs of both primary and revision total hip arthroplasties are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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