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Long-Term Outcomes of Birmingham Hip Resurfacing Arthroplasty

A Systematic Review of Independent Series with At Least 10 Years of Follow-up

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Background: Hip resurfacing arthroplasty (HRA) provides an attractive alternative to total hip arthroplasty (THA) for the management of osteoarthritis in younger, more active patients; however, concerns persist over complications specific to HRA. The aims of this systematic review were to assess the documented long-term survival rates of the metal-on-metal BIRMINGHAM HIP Resurfacing System at a follow-up of at least 10 years and to analyze the functional outcomes and cause of failures.

Methods: A systematic review was undertaken of all published cohort studies available in the MEDLINE, Cochrane, Embase, and PubMed research databases up to December 2021, as recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Data extraction was focused on survival rates, causes of failure, and functional outcomes. Survival estimates at 10 years were pooled in a meta-analysis, with each series weighted by its variance. Causes of failure were presented as a percentage of the pooled revisions.

Results: A total of 11 studies were identified, encompassing 3,129 cases. Across the 9 studies that had reported a mean follow-up, the mean follow-up was 11.7 years (range, 9.55 to 13.7 years). We found a pooled 10-year survival rate of 95.5% (95% confidence interval, 93.4% to 97.1%). There were 149 revisions among the studies (range, 4 to 38 revisions per study), a rate of 4.8% of the total procedures performed. The 2 main causes of revision were aseptic loosening (20.1% of revisions) and adverse reactions to metal debris (20.1%). There were no revisions for dislocation. Of the studies that reported preoperative functional scores, all reported significant improvement in mean scores postoperatively except for 1 study in which the mean Tegner activity score did not significantly improve.

Conclusions: When performed for appropriate indications, patients undergoing an HRA with use of the BIRMINGHAM HIP Resurfacing System can expect good implant survivorship at 10 years with acceptable functional results and low rates of dislocation and infection. This systematic review, however, confirms concerns regarding adverse reactions to metal debris as a leading cause of revision.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Hip resurfacing arthroplasty (HRA) provides an attractive alternative to total hip arthroplasty (THA) for the management of osteoarthritis in younger, more active patients. It has been documented that HRA can offer better function in certain patients[1-3] as well as a more normal gait[4] and that it has lower rates of infection and dislocation than THA[2,5]. Additionally, in HRA, femoral bone stock is preserved to aid in subsequent revisions[2,6]. HRA has also been reported to be associated with a lower mortality rate than THA[7,8].

The metal-on-metal BIRMINGHAM HIP Resurfacing System (Smith+Nephew) is the most widely utilized implant in HRAs worldwide. It uses large-diameter metal-on-metal components to optimize wear characteristics and to enhance stability while preserving femoral bone stock[9]. It has shown

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encouraging results in both independent series and registry studies, with the best results achieved in young, active male patients[10]. Despite these findings, the use of primary HRA has been declining worldwide as a result of concerns over complications specific to HRA, such as adverse tissue reactions to metal debris[11] and pseudotumors[12].

The objectives of this systematic review were to analyze the long-term survival rates of the BIRMINGHAM HIP Resurfacing System (BHR), the cause of failures, and the functional outcomes at a follow-up of at least 10 years. To our knowledge, this is the first systematic review of long-term studies on this topic with at least 10-year follow-up.

Materials and Methods

Literature Search and Study Selection

We performed a systematic review of published cohort studies in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Eligible studies were identified through a systematic search of the MEDLINE, PubMed, Embase, and Cochrane databases that was performed from commencement until December 2021. Database search terms included "hip resurfacing," "outcome," "follow-up," and "failure" to maximize sensitivity and specificity. Only prospective and retrospective longitudinal studies were considered. We reviewed the bibliographies of all retrieved studies for additional relevant articles.

Three authors (J.M., C.H., and J.C.) independently screened the titles and abstracts for eligibility. Studies that met the following 4 criteria were deemed eligible: (1) use of the metal-on-metal BHR prosthesis; (2) reporting of primary HRA survivorship, complications, and/or functional outcomes; (3) mean and/or median follow-up of at least 10 years; and (4) an independent cohort series. Studies must have been published in full and in English. Registry cohort studies and studies that reported results after revision of an HRA were excluded. If articles described the same series of patients, we included the most recently published series with the largest patient population. Disagreement between the authors was resolved by consensus.

Data Extraction and Quality Assessment

Three authors (J.M., C.H., and J.C.) independently extracted relevant data with use of a standardized form and recorded it in a protected database. We recorded, when available, data regarding publication year, the number of HRAs, patient age, patient sex, indications for the index surgery, loss to follow-up, functional outcomes, indications for revision, and summary implant survival estimates (including confidence intervals [CIs]) at 10 years, as well as data necessary for quality assessment. We did not extract data from figures to prevent potential inaccuracies.

Three authors (J.M., C.H., and J.C.) independently assessed the methodology and quality of data in the eligible studies. Study quality was judged with use of a previously described nonsummative 4-point system that evaluated whether or not the following elements were present: consecutive cases, multicenter, under 20% loss to follow-up, and using multivariable analysis[13].

Statistical Analysis

We performed all statistical analyses with use of R (R Foundation for Statistical Computing). We utilized descriptive statistics to summarize patient demographics, outcome measures, and revisions. HRA implant survival estimates at 10 years were pooled in a meta-analysis, with each series weighted by its variance (calculated from published CIs) using a fixed-effects model. Studies that did not report CIs for the survival estimate were excluded from the pooled analysis but included in the discussion.

Results

The initial search result yielded 343 potentially relevant articles after duplicates were excluded. A total of 291 articles were excluded following abstract review, and 42 additional articles were excluded following full-text review. During examination of the reference lists of the studies, 2 additional articles were identified for potential inclusion. One study was excluded for being a duplicate patient series. A total of 11 studies[14-24] were included in the present systematic review.

Study Design, Surgical Technique, and Implant Selection

A retrospective cohort study design was utilized in the majority (6; 55%) of the 11 included studies, and a prospective design was utilized in the remaining studies (5; 45%). As per our inclusion criteria, all studies assessed the BHR prosthesis. The studies utilized primarily the same surgical technique, a standard posterior approach with cementless acetabular and cemented femoral components, and all patients were mobilized early as tolerated.

Patient Demographics and Characteristics

A total of 3,129 primary HRAs performed in 2,812 patients between 1997 and 2006 were included. The demographic data of the patients are summarized in Table I. The mean age was 50.6 years, and 66.3% of the procedures were performed in male patients. Primary osteoarthritis was the indication in 79.0% of cases, excluding those from the study by Scholes et al.[14], in which procedures were performed for osteoarthritis of any etiology. Hunter et al.[15] and Scholes et al.[14] did not report the mean follow-up, but each had a minimum follow-up of 10 years. Among the remaining studies, the mean follow-up was 11.7 years (range, 9.55 to 13.7 years). Across all 11 studies, a total of 125 patients (4.4% of patients) died of causes not related to their HRA, with the number of patients who died per study ranging from 0 to 66. Across all studies, a total of 112 patients (4.0% of patients) were lost to follow-up, with the number of patients lost to follow-up per study ranging from 0 to 31.

Implant Survivorship, Complications, and Reoperations

All 11 studies reported 10-year survival rates (range, 91% to 98%) with all-cause revision as an end point; however, data from the studies by Hunter et al.[15] and Azam et al.[16] were excluded from the pooled survival rate because CIs were not reported. A pooled analysis of the identified studies produced a 10-year survival rate of 95.5% (95% CI, 93.4% to 97.1%) with all-cause revision as an end point (Fig. 1).

TABLE I Study Characteristics and Demographics*

Study	Year	Location	Study Design	No. of HRAs	Mean Age *(yr)*	Male *(%)*	OA Indication *(%)*	Mean Follow-up *(yr)*	Died *(no.)*	Lost to Follow-up *(no.)*	Implant Survival Rate *(%)*	95% CI *(%)*
Coulter et al.[17]	2012	Australia	Retrospective	230	52.1	65.7	88.2	10.4	6	16	94.5	90.1-96.9
Holland et al.[18]	2012	U.K.	Prospective	100	51.3	74	79.0	9.55	0	2	92	86.7-97.3
Matharu et al.[19]	2013	U.K.	Prospective	447	41.5	59.5	68.0	10.14	13	0	96.3	93.7-98.3
Van Der Straeten et al.[20]	2013	Belgium	Retrospective	250	50.6	69.6	80.8	10.8	18	15	92.4	90.8-94
Reito et al.[21]	2014	Finland	Retrospective	261	53.7	68	91.3	10.4	2	22	91	89-93
Daniel et al.[22]	2014	U.K.	Prospective	1,000	53	66.5	76.0	13.7	66	0	97.4	96.9-97.9
Azam et al.[16]	2016	Australia	Retrospective	244	58.3	68.9	100.0	12.05	0	31	93.7	–
Mehra et al.[23]	2015	U.K.	Prospective	120	50	52.5	56.6	10.8	9	13	94.2	88.8-98.7
Moroni et al.[24]	2017	Italy	Retrospective	100	48.9	58	66.0	10.8	3	3	98	90-100
Hunter et al.[15]	2018	U.K.	Retrospective	139	52.5	63	86.0	≥10	8	10	91	–
Scholes et al.[14]	2019	Australia	Prospective	238	45	79.8	100	≥10	0	0	96.8	94.2-99.4
All studies†				3,129	50.60	66.3	79.00‡	11.70§	125	112	95.45#	93.35-97.08#

*OA = osteoarthritis, U.K. = United Kingdom. †Values are given as the total or average across all studies, except as noted. ‡Excludes Scholes et al. §Excludes Hunter et al. and Scholes et al. #Excludes Hunter et al. and Azam et al.

There were a total of 149 revisions across the studies (range, 4 to 38 revisions per study), a rate of 4.8% of total procedures performed. The 2 main causes of revision were aseptic loosening (20.1% of total revisions) and adverse reactions to metal debris (20.1%), followed by atraumatic femoral neck fracture (12.8%), femoral head collapse (10.7%), pain (10.1%), infection (8.7%), osteonecrosis (7.4%), and osteolysis (4.7%). The remaining 8 revisions (5.4%) were for "other" causes, which included 2 revisions for malposition and 4 for traumatic or pathological fractures. There were no revisions for dislocation in this pooled cohort (Fig. 2).

Functional Outcomes

Of the 11 studies, 9 reported mean functional scores at the latest follow-up, and 6 of these studies reported preoperative functional scores. A total of 7 studies reported the Harris hip

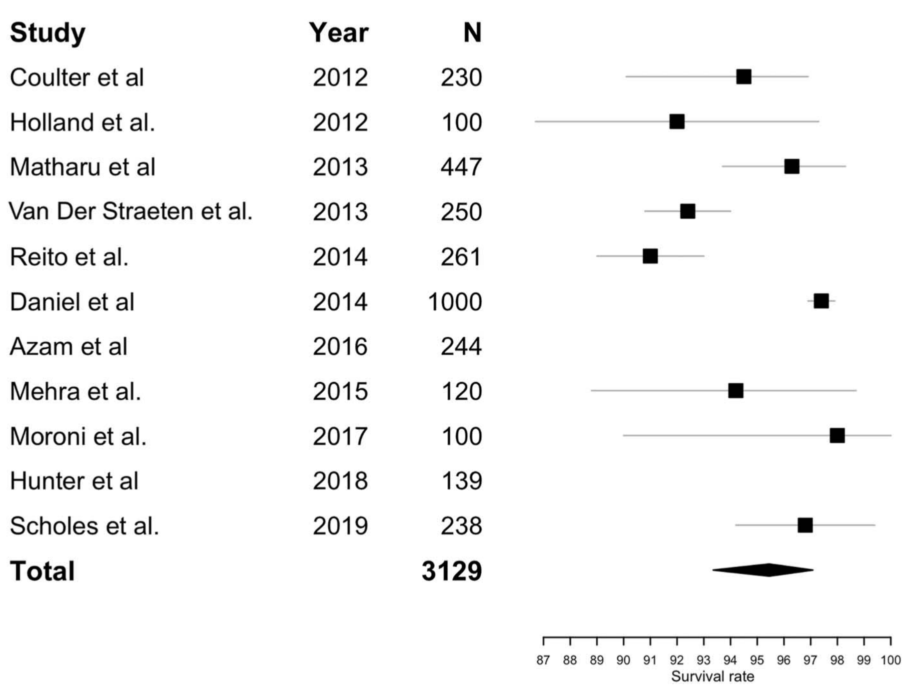

Fig. 1

Forest plot showing survival rates.

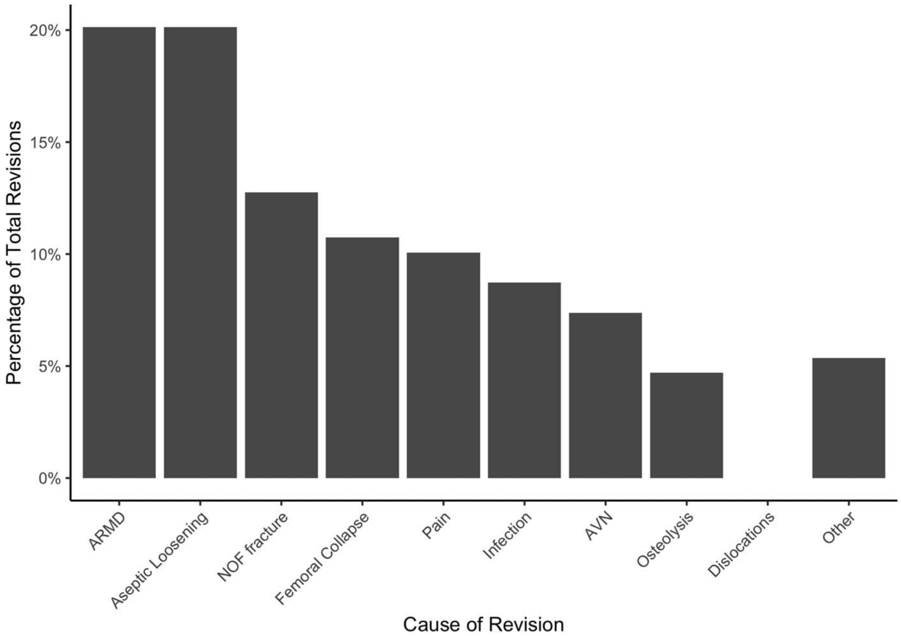

Fig. 2
Bar graph showing causes of revision. ARMD = adverse reactions to metal debris, NOF = neck of femur, AVN = avascular necrosis (osteonecrosis).

score (HHS)[25], 5 studies reported the University of California Los Angeles (UCLA) activity score[26], and 4 studies reported the Oxford Hip Score (OHS)[27]. The Hip disability and Osteoarthritis Outcome Score (HOOS)[28], Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[29], and the Tegner activity score[30] were reported in 1 study each. Of the studies that reported preoperative functional scores, all reported significant improvement in mean scores postoperatively except for the Scholes et al. study, in which the mean Tegner activity score did not significantly improve. Collated mean functional scores are presented in Table II. A meta-analysis was not performed because variances were not reported in all studies.

Study Quality

A quality assessment of the cohorts of each study revealed that all 11 studies had consecutive patients. All 11 studies had <20% loss to follow-up, of which 8 had <10% loss to follow-up. Six (55%) of the 11 studies performed a multivariable analysis. Data were not reported on whether the studies were multicenter; however, only 1 of the 11 studies analyzed procedures performed by multiple surgeons. Therefore, this sample represents high-quality cohort studies with consecutive patients and minimal loss to follow-up and includes results from both designer and non-designer surgeons.

Discussion

Third-generation hip resurfacing prostheses, including the BHR, have shown encouraging short-term success, whereas previous generations had been largely unsuccessful[31]. The BHR provides the theoretical benefits of femoral bone-stock preservation, restoration of biomechanical hip parameters, and physiological femoral loading[32,33].

However, there has been a decrease in the number of HRAs being performed worldwide, partially due to the recall of poor-performing designs[34,35], the recognition of complications unique to HRA[11,12], and more selective indications[36]. Among hip resurfacing prostheses, the BHR is one of the most utilized and best-performing[37] and has the most comprehensive long-term follow-up data published. We utilized individual study estimates weighted by CIs to predict a pooled survival rate of the BHR at a follow-up of 10 years, and, to our knowledge, this systematic review represents the first of its kind to do so.

An acceptable medium-term survival rate of >90% remains the goal in managing osteoarthritis of the hip in young patients[38]. We found a pooled 10-year survival rate of 95.5% across the 9 cohort studies (designer and non-designer) with a mean follow-up of at least 10 years and CIs for survival. This rate is higher than the 93.4% 10-year survival rate reported for the BHR by the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) and is comparable to the cumulative implant survival rate for THA at 10 years, which ranges from 91.3% to 96.8% depending on the prosthesis and cementation type[39]. The mean age of our pooled cohort was 51 years, and most procedures were performed in male patients for osteoarthritis. These patient characteristics largely reflect the refinement of indications for HRA following early studies that showed a high failure rate in female patients, potentially due to smaller prosthesis bearings[38]. Among conventional THAs performed for osteoarthritis in patients <55 years old, the 10-year implant survival rate has been reported to be 94.9% for male patients and 94.7% for female patients[39]—rates that are marginally lower than our pooled survival estimate. The similarity in long-term implant longevity between the BHR and conventional THA highlights the potential role of HRA for younger patients.

TABLE II Study Functional Scores*

Study	Functional Outcome	Mean Preop. Score	Mean Postop. Score	P Value
Coulter et al.[17]	OHS	–	45	
	UCLA activity	–	7.4	
	HOOS	–	5.4	
Holland et al.[18]	HHS	–	96	
	UCLA activity	–	7	
Matharu et al.[19]	OHS	19.2	46	0.02
	UCLA activity	–	6	
Van Der Straeten et al.[20]	HHS	–	97.7	
Reito et al.[21]	HHS	56	100	
Daniel et al.[22]	HHS	58	94	<0.001
	UCLA activity	–	7.8	
Mehra et al.[23]	HHS	44.5	84	
Moroni et al.[24]	OHS	29.1	47.7	<0.001
	HHS	58	98.6	<0.001
	UCLA activity	4.9	8.2	<0.001
Hunter et al.[15]	OHS	–	–	<0.001
Scholes et al.[14]	mHHS	–	96	
	Tegner	3	3	0.743
	WOMAC pain	9.5	1	<0.001
	WOMAC function	34	5	<0.001
	WOMAC motion	4.5	1	<0.001

*OHS = Oxford Hip Score, UCLA = University of California Los Angeles score, HOOS = Hip disability and Osteoarthritis Outcome Score, HHS = Harris hip score, mHHS = modified HHS, Tegner = Tegner activity score, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index. P < 0.05 was significant.

It has been documented that HRA can offer better function in certain patients and has lower rates of infection and dislocation than THA. Reassuringly, there were no revisions for dislocation in our pooled cohort. This finding is in stark contrast to conventional THA, for which dislocation has been reported to account for 22.5% of revisions[39]. Additionally, in the present study, infection accounted for 8.7% of all HRA revisions. This percentage is lower than the 22.3% reported for THA by the AOANJRR, which noted that young male patients had a disproportionately high rate of infection-related revisions[39]. The reduced rates of dislocation and infection are of specific importance in young active patients who want to preserve function. Studies have shown that HRA is associated with a lower mortality rate than conventional THA[7,8], which was confirmed in the present study, as our pooled analysis showed that only a small number of patients (4.4%) died. The authors of the aforementioned studies did not suggest a reason for this finding, and it remains unclear if it was the result of selection bias or an effect of the surgery. We note that a proportion of the 4% of the cohort lost to follow-up in the present study may represent deaths and hence the mortality rate may be underestimated.

Younger patients are now seeking hip replacements to restore high-impact and active lifestyles[40]. In the present systematic review, all studies comparing preoperative and postoperative functional scores reported significant improvement except for the study by Scholes et al., which showed no change in the Tegner activity score. Among the studies that reported UCLA activity scores, only 1 study reported a mean score of <7. This result indicates that, in most of those studies, patients were still regularly participating in active events such as bicycling. Only 1 study reported a mean HHS of <94, and all of the reported mean postoperative scores for the OHS were ≥45, illustrating acceptable postoperative function at 10-year follow-up.

Although we found that the BHR was associated with acceptable functional outcomes and long-term survivorship and had lower rates of infection and dislocation than THA, our pooled analysis confirmed concerns over adverse reactions to metal debris. This complication was tied for the most prevalent cause of failure, accounting for 20% of revisions in the pooled cohort. Reactions to metal debris released from the metal-on-metal bearing result in large sterile effusions and soft-tissue changes, known as pseudotumors, that largely remain asymptomatic while causing destruction of local muscle and bone[41]. Edge-loading of the metal-on-metal bearing results in metal debris and has been shown to be a particular issue in female patients and patients with smaller bearing sizes[42]. Excessive acetabular inclination or anteversion has also been reported to cause an increased production of metal debris, with the risk of pseudotumors reduced for an acetabular component orientation of 35° to 55° inclination and 10° to 30° anteversion[43]. Reassuringly, contrary to previous observations[44,45], it is now documented that metal-on-metal HRAs revised for adverse reactions to metal debris have approximately half the risk of re-revision compared with revisions for other indications[46]. Conventional THAs with large-diameter metal-on-metal bearings have demonstrated a very high 10-year revision rate of 22.6%[39]; however, substantial improvement has been made with the development of ceramic-on-ceramic and metal-on-crosslinked-polyethylene bearings, for which 10-year revision rates of 5.0% and 4.6%, respectively, have been documented[39]. It is not unreasonable to expect that similar improvements in survivorship may be achieved with the introduction of modern bearings in HRA.

Additionally, the present systematic review illustrates that aseptic loosening, femoral neck fracture, femoral head collapse, and osteonecrosis were also notable reasons for HRA revision. Although the cause of these problems is likely multifactorial, the preparation of the femoral head, the cementing technique utilized, and the subsequent positioning of the femoral component have important implications for the survival of the prosthesis[5]. The optimal cement mantle and penetration have not been documented for THA. In total knee arthroplasty, a cement penetration of 2 to 5 mm into bone has been reported to be optimal for the fixation of components in cancellous bone[47], as a cementation depth of 2 to 3 mm is required to engage at least 1 level of transverse trabeculae[48]. An excessive cement penetration of >6 mm and large cement masses have been shown to result in high intraosseous temperatures, potentially resulting in thermally induced osteonecrosis[49]. It has also been proposed that deep cementing may jeopardize the ability of femoral trabecular bone to withstand dynamic stresses[49]. Because radiographic analysis of HRA in vivo is severely hindered by artifacts from the metal-on-metal bearing, the only ways to assess the impact of cement penetration currently are through cadaveric studies or retrieval studies following prosthesis failure, which limits our understanding of this important risk factor.

Limitations

This review has several limitations. Our pooled survival estimate did not stratify patient factors that may potentially influence survivorship, such as age, sex, and primary indication. Additionally, although the mean age was generally comparable across the studies, 2 studies examined only patients <55 years old, which could have skewed the results. The pooled patient population in this review was relatively young (mean age, 50.6 years); therefore, a 10-year follow-up may not have been adequate and a longer follow-up is required to confirm these findings. We were unable to consider surgeon factors that affect survivorship, such as the threshold for performing a revision, which may vary between surgeons. Finally, most of the included studies were retrospective cohort studies, and, although each cohort study was individually of high quality, cohort studies are of lower methodological quality overall. This resulted in missing data, with 2 studies being excluded from the pooled survival rate.

The present systematic review provides an aggregated estimate for survival in all patients, and, to our knowledge, is the first of its type with this length of follow-up. Additionally, the included studies were from a variety of centers and consisted of both designer and non-designer cohorts.

Conclusions

When performed for appropriate indications, patients undergoing an HRA with use of the BHR can expect good implant survivorship at 10 years with acceptable functional results and a low rate of dislocation. Such results are particularly important for young active individuals. However, this systematic review confirms concerns over adverse reactions to metal debris as a leading cause of revision. Additionally, the factors leading to femoral neck fractures and osteonecrosis merit further attention. We conclude that there is great potential for the continued use of HRA, although longer-term follow-up is required. ■

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