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ORIGINAL ARTICLE

Medicine Science 2021;10(4):1327-32

Medicine Science International Medical Journal

Medial support is the critical risk factor for preventing failure after plating of proximal humerus fractures

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Received 21 April 2021; Accepted 08 June 2021
Available online 04.10.2021 with doi: 10.5455/medscience.2021.04.130

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Abstract

The purpose of this study was to evaluate the risk factors of failure of fixation after locked plating of proximal humerus fractures. The study included displaced 71 proximal humerus fracture operation cases at a single centre between January 2016 and June 2020. All humeral fixation surgeries were performed with a proximal humerus locked plate. The primary outcome measure was failure of fixation. Age, gender, mechanism of injury, operated side, type of fracture, type of anesthesia, ASA score, surgical approach, presence of medial cortical support, neck-shaft angle, medial metaphyseal extension of fracture, medial hinge displacement, number of humeral head screws, number of calcar screws were the assessed variables. Newly proposed risk factors including lateral humeral offset (LHO), lateral glenohumeral offset (LGHO), humeral head diameter (HHD), LGHO/HHD ratio were also assessed radiologically. This study showed that lack of medial support was the only significant factor for the failure of proximal humerus fracture osteosynthesis ($p < 0.001$). Failure of surgery was determined in 14 out of 37 cases who had lack of medial support. Proximal humerus fractures should be anatomically reduced, especially surgeons should obtain the medial support in order to decrease the probability of loss of fixation after surgery.

Keywords: Proximal humerus fracture, locked compression plating, medial support, Neer classification

Introduction

Proximal humerus fractures are the most common upper extremity fracture type following distal radius fractures and occur mainly on the basis of osteoporosis. As the elderly population increases around the world, the frequency of proximal humerus fractures also increases and stands out as a major public health problem. Although successful results are usually feasible with conservative methods, the most preferred surgical method remains as open reduction and internal fixation with proximal humerus locked plates(PHLP) to obtain bony union and good alignment in displaced fractures [1,2]. PHLP is thought to obtain angular stability and have greater mechanical advantages over conventional plating in case of osteoporosis [3]. Different studies reported varying complication rates of PHLP [4,5]. Loss of reduction is a significant complication that can occur after PHLP surgery and was shown to be the most common cause for revision surgeries [6]. Some risk factors have been evaluated to determine what causes loss of fixation, but no consensus has yet been reached [7,8]. Therefore, this study aimed to investigate the predictive risk factors leading to failure after PHLP of proximal humerus fractures. The determination of these factors will lead us to have better understanding of proximal humerus fractures and help to improve the surgical results.

Materials and Methods

Patient selection

The present study is an institutional review board approved retrospective study(The ethical committee of Isparta City Hospital, IRB number:12.02.2021,4/84,). It was conducted on consecutive patients with proximal humerus fractures at a single center between January 2016 and June 2020. All patiens underwent open reduction and internal fixation with a proximal humerus locked plate.

The inclusion criteria were as follows: (i) age at least 18 years, (ii) having at least six-month follow-up, (iii) acute fracture less

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than two weeks, (iv) complete chart data. The patients who had nonunion, pathological fracture, refracture, diaphyseal extension, concomitant neurovascular injury, polytrauma, additional ipsilateral injury in the same arm in the past or present were excluded. Finally 71 remaining patients of those who met the inclusion criteria were further analysed (Figure 1).

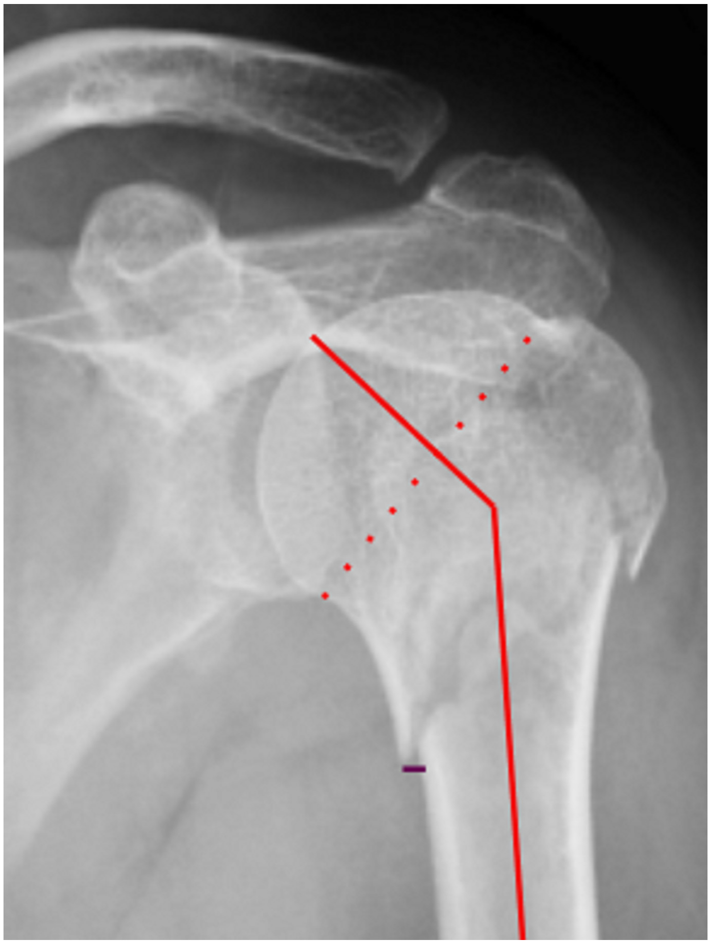

Figure 1. Preoperative NSA and medial displacement measurement (red lines form NSA, purple line shows the medial displacement)

Surgical protocol

All patients were operated in the beach chair position under general or regional anesthesia. Two surgical exposures were used: deltopectoral approach and transdeltoid lateral approach. The conventional deltopectoral incision was extended from the coracoid to the insertion of deltoid muscle. The cephalic vein was dissected and protected through the procedure if possible. The lateral approach was extended from the anterolateral edge of the acromion to distally along the diaphysis. The deltoid muscle was splitted through anterior and middle portions. The axillary nerve was palpated and identified if needed to protect during the surgery. After reduction of the tuberosities and the fragments using Kirschner wires, PHLP(TST, Istanbul, Turkey) was applied lateral to biceps tendon under the axillary nerve, subsequently tuberosities were sutured via nonabsorbable sutures to the plate in both surgical approaches. All patients had three weeks sling immobilization, followed by passive and active assisted rehabilitation program. The patients started active range of motion exercises after six weeks routinely.

The data were collected from the medical records of our hospital. Age, gender, mechanism of injury, operated side, surgical approach, type of anesthesia were the baseline characteristics (Table 1).

The standardized preoperative, immediate postoperative, third month and sixth month postoperative shoulder roentgenograms in three planes (anteroposterior, trauma axillary, and oblique views) were evaluated using PACS(Picture Archiving Communication Systems). All fractures were classified according to the Neer classification system [9]. The computed tomography scans were used when the fracture could not be classified through the X-ray views as the preference of the reviewer.

The primary outcome measure was the failure of surgery. The surgery was deemed as a failure as follows: (i) screw penetration into the shoulder joint, (ii) avascular necrosis of the humeral head, (iii) implant failure (screw cut out or breakage of plate), (iv) deep infection, (v) implant related subacromial impingement, and (vi) reduction loss. Reduction loss was defined as (1) > 10 degrees of angulation in any direction, (2) > 5 mm of height loss of the humeral head from the plate. Reoperations were also noted for all patients. Based on Gardner et al. 's study, medial support was deemed as present in the case of: 1) not having medial comminution and anatomically reduced (displacement less than 2 mm on the medial side), 2) having approriate at least one inferomedial calcar screw within 5 mm of the humeral head subchondral bone [10]. Contrarily, the fractures which did not obtain these criteria were accepted to have inadequate medial support.

The other assessed parameters were:

1) Neck-shaft angle (NSA): The angle is formed between the line which bisects the humeral diaphysis and the perpendicular line to the superior border and the inferior border of articular surface (Figure-1 and 2). The initial displacement of the humeral head was measured using NSA in coronal plane from preoperative X-rays and the same measurement was repeated on the immediate postoperative views and sixth month views. The varus malalignment was accepted below 120°, neutral alignment between 120°-140° and valgus malignment above 140°. Loss of fixation was defined as a change of greater than 10° in the NSA angle during follow up.

2) Medial metaphyseal extension of fracture: The limit is accepted as 8 mm.

3) Medial hinge displacement

4) Number of humeral head screws

5) Number of calcar screws

6) Lateral humeral offset (LHO): LHO is defined as the distance between the lateral point of coracoid process and the most lateral point of greater tuberosity (Figure-3).

7) Lateral glenohumeral offset (LGHO)/ Humeral head diameter (HHD): LGHO is defined as the distance between the most medial point of the glenoid cavity and the most lateral point of greater tuberosity. HHD is defined as the distance between the just medial point of the anatomical neck and the junction point where head and greater tuberosity meets [11] (Figure-3).

Table 1. Demographic data of the all patients

	Patients with proximal humerus fracture	
	Mean ± SD	**Min-Max**
Age, years	61.2 ± 14.7	21-91
Gender, Female/Male	48(67.6%)/23(32.4%)	
Side, Right/Left	36(50.7%)/35(49.3%)	
Fracture type (Neer Classification)		
Type 2, n(%)	18(25.4%)	
Type 3, n(%)	42(59.2%)	
Type 4, n(%)	11(15.5%)	
Fracture Mechanism		
Simple fall, n (%)	46 (64.8%)	
Motor vehicle accident, n (%)	23 (32.4%)	
Industrial Injury, n (%)	2 (2.8%)	
Anesthesia type		
General, n (%)	51 (71.8%)	
Regional, n (%)	20 (28.2%)	
ASA Score		
1, n (%)	5 (7%)	
2, n (%)	52 (73.2%)	
3, n (%)	13 (18.3%)	
4, n (%)	1 (1.4%)	
Surgical exposure		
Deltopectoral, n (%)	52 (73.2%)	
Anterolateral, n (%)	19 (26.8)	
Medial Support		
Yes, n (%)	34 (47.9%)	
No, n (%)	37 (52.1%)	
Failure		
Yes, n (%)	15 (21.1%)	
No, n (%)	56(78.9%)	
LGHO(mm)	50.95±14.7	32-66
LHO(mm)	57.87±9.3	18-75
LGHO/HHD Ratio	1.07±0.14	0.64-1.44
HHD	47.51±4.5	34-60
Humeral head-plate distance(mm)	9.8±7.9	-9.4-50
Preop NSA(degrees)	136.7±22.27	46-175
Postop NSA(degrees)	130.44±11.5	80-162
Last follow-up NSA(degrees)	129.9±12.2	80-160
Preoperative medial displacement (mm)	7.45±8.3	0-37.3
Postoperative medial displacement (mm)	2.9±3.7	0-16
Number of screws in the humeral head	6.9±1.5	5-10
Number of calcar screws	0.97±0.8	0-3

ASA: American Society of Anesthesiologists, LGHO: Lateral Glenohumeral Offset, LHO: Lateral Humeral Offset, HHD: Humeral Head Distance, NSA: Neck-Shaft Angle

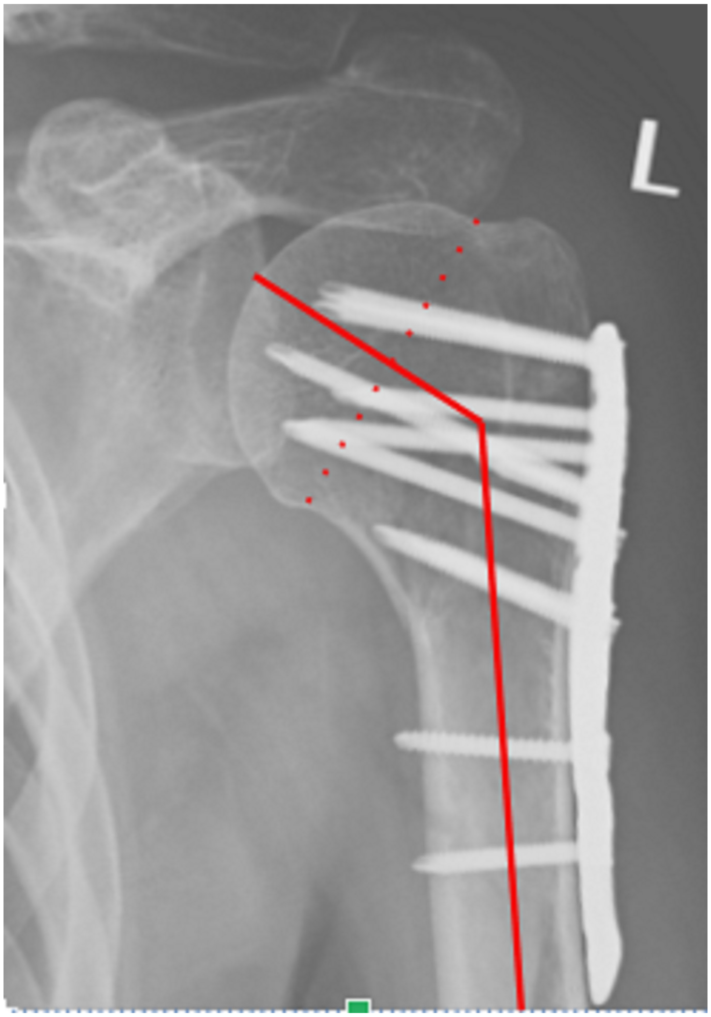

Figure 2. Postoperative NSA measurement (medial anatomically reducted and there is not any medial displacement)

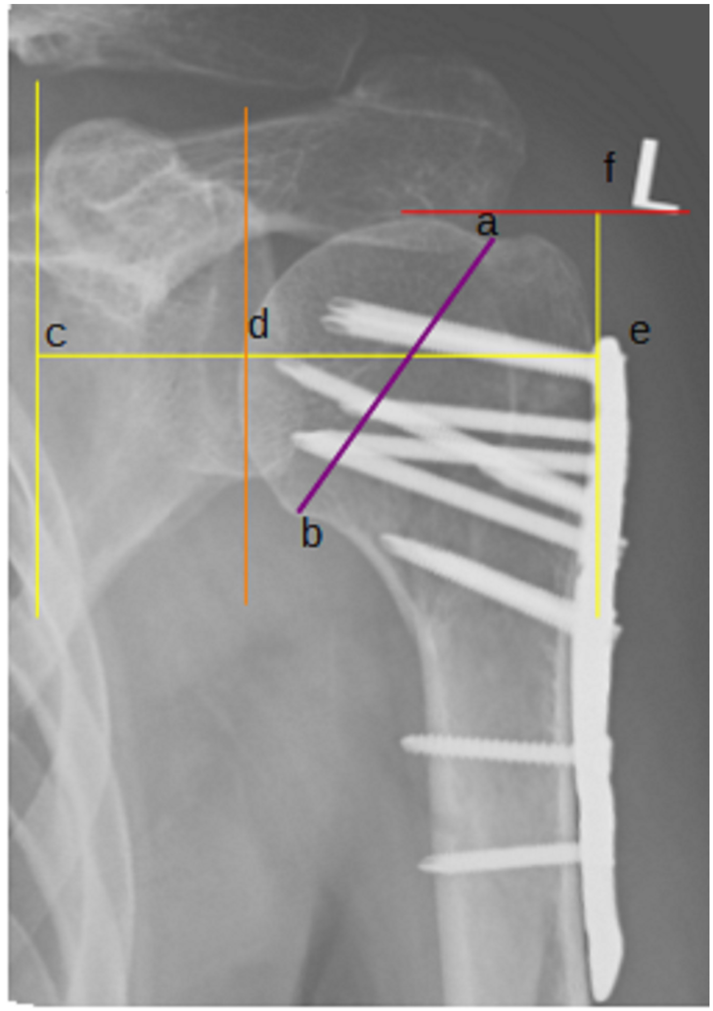

Figure 3. Postoperative measurements (ab: Humeral head diameter, ce: Lateral humeral offset, de: Lateral glenohumeral offset, fe: Humeral head-plate distance)

Statistical analysis

Statistical analyses were performed using SPSS software (SPSS version 21, Chicago,Illinois). P-values <0.05 were considered significant. Metric scaled data are reported as arithmetic mean standard deviation and categorical data with frequency. Student t-test for independent variables or a nonparametric Mann–Whitney U-test was used for the comparison of metric scaled data for two groups. The distribution pattern of the groups was determined using the Kolmogorov–Smirnov test. A Chi-square test or a Fisher's Exact test was used for the analysis of categorical data.

Results

Seventy-one proximal humerus fracture patients who met the inclusion criteria were included in this retrospective study. Forty-eight (68.6 %) of them were females and 23 (31.4 %) of them were males. The mean age of the patients was 84.2 ± 7 (range, 21 to 91). Simple fall was the most common injury mechanism (64.8%), followed by motor vehicle accident (32.4%). The fractures were classified as Neer 2 in 25.4% (n:18), Neer 3 59.2% (n:42), and Neer 4 in 15.5% (n:11). The deltopectoral approach was chosen in 73.2% (n:52) of the surgeries, whereas lateral approach was chosen in 26.7% (n:19). The baseline characteristics are shown in Table 1.

Medial support was obtained in 34 (52.1%) patients. The overall incidence of failure was observed in 15 (21.1%) cases. This study showed that lack of medial support was the only significant factor for the failure of proximal humerus fracture osteosynthesis (p <0.001). Failure of surgery was determined in 14 out of 37 cases who had lack of medial support. Contrarily, only one patient had failure when the medial support was obtained intraoperatively. The surgical approach did not significantly affect the failure rates between groups (p:0.53). The other researched parameters including age, gender, anesthesia type, Neer classification, ASA score, LGHO, LHO, LGHO/HHD ratio, preoperative-postoperative NSA, last follow-up NSA, medial head extension, preoperative-postoperative medial displacement, the number of head screws, the number of calcar screws were not also found to be significant (p >0.05). The comparison of categorical data between groups are shown in Table 2 and the numerical variables are shown in Table 3.

Four patients needed a reoperation surgery in the first postoperative six months: three of them were revised with reverse shoulder arthroplasty and one was revised with hemiarthroplasty. The other 11 patients were not revised due to refusal of the second surgery.

Table 2. Categorical variables according to failure of surgery

		Failure		
		No	**Yes**	
Gender	**Female n(%)**	38(79.2%)	10(20.8%)	p:1
	Male n(%)	18(78.3%)	5(21.7%)	
Anesthesia type	**General, n(%)**	41(80.4%)	10(19.6%)	p:0.74
	Regional, n(%)	15(75.0%)	5(25.0%)	
Surgical exposure	**Deltopectoral, n(%)**	42(80.8%)	10(19.2%)	p:0.53
	Anterolateral, n(%)	14(73.7%)	5(26.3%)	
Neer Fracture Classification	**Type 2, n(%)**	13(72.2%)	5(27.8%)	p:0.6
	Type 3, n(%)	33(78.6%)	9(21.4%)	
	Type 4, n(%)	10(90.9%)	1(9.1%)	
ASA score	**Low(1-2), n(%)**	48(84.2%)	9(15.8%)	p:0.06
	High(3-4), n(%)	8(57.1%)	6(42.9%)	
Medial support	**No, n(%)**	23(62.2%)	14(37.8%)	p<0.001*
	Yes, n(%)	33(97.1%)	1(2.9%)	

ASA: American Society of Anesthesiologists

Table 3. Comparison of numerical data according to failure

	Failure		
	No (n:56)	**Yes (n:15)**	
Age(years)	60.6±14.6	63.5±15.4	p:0.5
LGHO(mm)	50.5±6.8	52.4±9.9	p:0.39
LHO(mm)	57.8±7.6	58.2±14.4	p:0.92
LGHO/HHD ratio	1.06±0.1	1.1±0.1	p:0.39
HHD(mm)	47.6±5.1	47.1±6.9	p:0.77
Humeral head-plate distance(mm)	10.1±7.8	8.9±8.1	p:0.61
Preop NSA(degrees)	135.7±22.8	140.5±	p:0.45
Postop NSA(degrees)	130.7±8.2	129.6±19.9	p:0.84
Last follow-up NSA(degrees)	131±3±8.2	124.8±21.3	p:0.26
Medial head extension(mm)	7.27±9.1	7.26±8	p:0.99
Preoperative medial displacement(mm)	6.6±7	10.6±11.7	p:0.22
Postoperative medial displacement(mm)	2.7±3.5	3.9±4.3	p:0.29
Number of screws in the humeral head	7±1.3	6.7±1.4	p:0.36
Number of calcar screws	1±0.8	0.8±0.9	p:0.34

ASA: American Society of Anesthesiologists, LGHO: Lateral Glenohumeral Offset, LHO: Lateral Humeral Offset, HHD: Humeral Head Distance, NSA: Neck-Shaft Angle

Discussion

All osteosynthesis surgeries aim to ensure strong stability, rigidity and maintenance of alignment achieved in surgery until union is obtained. Loss of fixation emerges a serious problem as with proximal humerus fractures that develop on the basis of osteoporosis. Specially contoured locked plating systems which present more rigidity and angular stability than conventional plating have been developed to prevent failures and achieve better clinical and functional outcomes but similar problems continue to occur with these implants. The orthopaedists will have the opportunity to manage both surgery and postoperative period in a different manner if the predictive factors that lead to failure after proximal humerus fractures can be clearly identified.

This study aimed to determine the risk factors that led to failure and found that lack of medial cortical support significantly contributed to the increased failure rates. Medial cortical support was not obtained in 14 out of 15 patients who failed after surgery. The reduction of the medial cortex is critical for a successful surgery and maintenance of reduction. We did not find the medial communition associated with failure. Lescheid et al. biomechanically investigated in two-part proximal humerus fractures using synthetic humerus and the stiffest construct was seen in anatomic reducted bones with medial cortical support and subsequent removal of medial cortical support were resulted in drastic effects in levels of stiffness [12]. The concept of medial cortical support was originally described and popularised by Gardner et al. who found that mechanical medial region is important for maintenance of reduction in proximal humerus locked plating and the locking screws alone are not enough for stabilisation of medial column without medial buttress [10]. They also proposed inserting at least one inferomedial calcar screw regardless of the proper anatomic medial reduction, although the number of calcar screws was not found to be a significant factor in this study. Krappinger et al. also determined medial support as well as age, bone density, anatomic reduction as the parameters to maintain the fixation of fracture and advised considering the primary arthroplasty as a choice in the case of intraoperative lack of anatomic reduction of medial support [7].

The locked plating of proximal humerus fractures are not out of the complications. Varus malunion, nonunion, avascular necrosis (AVN), screw perforation, plate irritation, infection, stiffness are the most common problems and usually require reoperations to achieve a functional and pain free shoulder [13]. AVN was observed in three patients, and shoulder arthritis occurred in two of those. Hertel et al. found the integrity of medial cortex, metaphyseal extension, and the basic fracture type as predictors of ischemia [14]. All of the AVN patients lacked medial support.

The deltopectoral approach and the lateral approach are both utilized for the plating of proximal humerus fractures. There has also been an increase in the frequency of lateral approach use with the increasing frequency of minimally invasive surgeries today. However, no superiority of one approach over the other was shown in the present study. A patient in the lateral approach group had numbness in the deltoid area postoperatively and immediately revised whether the axillary nerve was iatrogenically damaged. The axillary nerve was seen compressed under the calcar screw, the nerve was released and subsequently the fracture was replated. The patient did not need further reoperation. The lateral approach is known to carry much more axillary nerve damage risk and the surgeons should be careful during surgery while dissection or retraction of the axillary nerve which is located approximately five cm below the inferior side of the acromion [15].

This study has some several notable limitations. First, it was a retrospective study that caused difficulty in data collection. Also, some patients were excluded due to unavailable data and radiographic views. Surgical approaches for the patients were not randomized and it was determined as the preference of the operating surgeon. Although all cases were operated by specialists who had at least five years of experience, multiple surgeons were involved in the study. The number of patients was relatively small. Further larger sample sized prospective randomised studies should be done to reach more exact and specific conclusions.

Conclusion

Although PHLP is an important breakthrough in the fixation of proximal humerus fractures, failure of surgery is still an issue. Anatomical reduction and medial support should be provided to prevent these failures. None of the other risk factors have importance as medial support has to maintain reduction.

Conflict of interests
The authors declare that they have no competing interests.

Financial Disclosure
All authors declare no financial support.

Ethical approval
The present study is an institutional review board approved retrospective study(IRB number: 12.02.2021, 4/84).

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