Original Article

A Systolic Blood Pressure of 100 mm Hg Is Optimal for Optimal Visualization in Arthroscopic Rotator Cuff Repair in the Beach-Chair Position

Megumi Shingu, R.N., M.S., Nariyuki Mura, M.D., Ph.D., Tomohiro Uno, M.D., Ryuta Oishi, M.D., Tadashi Koseki, O.T., and Kaori Sakurada, M.D., Ph.D.

Purpose: To investigate the relationship between visualization and blood pressure during arthroscopic rotator cuff repair (ARCR) in the beach-chair position and to clarify the optimal blood pressure to maintain good visualization during surgery. **Methods:** One senior surgeon evaluated intraoperative visualization at the start of arthroscopy, at acromioplasty, at the refresh of the footprint on the greater tuberosity, at marrow vent creation in the footprint on the greater tuberosity, and at rotator cuff fixation. The evaluation grades were: 5, clear; 4, mild bleeding; 3, bleeding but operable; 2, poor visualization due to bleeding; and 1, inability to continue surgery due to massive bleeding. During ARCR, an arterial line was inserted, and blood pressure was measured continuously. The relationship between visualization and blood pressure was analyzed. Receiver operating characteristic analysis was performed with evaluation grades 5 and 4 as the good visualization group and the other evaluation grades as the poor visualization group. **Results:** Visualization assessment and systolic/diastolic blood pressure were associated at the start of arthroscopy ($P = .0257/.0057$), at acromioplasty ($P = .0023/.0399$), and at the refresh of the footprint ($P = .0201/.0272$). The average blood pressure of evaluation grade 5 cases was 91/50 mm Hg. The cut-off values, based on the area under the curve on receiver operating characteristic analysis, were as follows: 104/60 mm Hg (0.91-0.95) at acromioplasty; 116/70 (0.94-0.96) at the refresh of the footprint; 116/70 mm Hg (0.94-0.96) at the refresh of the footprint; and 106/58 mm Hg (0.73-0.70) at marrow vent creation. **Conclusions:** Good visualization during ARCR in the beach-chair position was significantly associated with blood pressure. An optimal blood pressure resulting in good visualization that would not cause excessive hypotension during ARCR surgery in the beach-chair position might be a systolic blood pressure of 100 mm Hg. **Level of Evidence:** III, prospective, nonrandomized, observational study.

In arthroscopic rotator cuff repair (ARCR), bleeding during surgery often results in poor visualization and delays the continuation of the surgery. It is therefore recommended that intraoperative hypotension be maintained to obtain good visualization. The patient's posture in ARCR is a 60° beach-chair position or the lateral decubitus position. The beach-chair position is similar to the sitting position. This is because the beach-chair position is close to the physiological posture, is advantageous for dynamic evaluation during the operation, and is easy to shift to open surgery.

In the lateral decubitus position, the arthroscope must be rotated 90° to perform surgery to display the acromion on the monitor screen to the head side. In contrast, in the beach-chair position, the image of the intra-articular structures is easier to understand than in the lateral decubitus position, and the absence of traction avoids neurological complications.[1,2] However, blood pressure is apt to decrease transiently during postural changes in the beach-chair position, and there is a risk of reduced cerebral perfusion pressure and embolism.[3-9] Shigetomi and Kudo[3] reported a case in which intraoperative blood pressure was maintained at 80-96/50-65 mm Hg but

From Yoshioka Hospital (M.S., N.M., T.U., R.O., T.K.), Department of Fundamental Nursing, Yamagata University Faculty of Medicine School of Nursing (M.S., K.S.); and Yamagata Prefectural University of Health Sciences (N.M.), Yamagata, Japan.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

This study was presented at the Orthopaedic Research Society (ORS) in February 2020.

Received April 14, 2021; accepted September 2, 2021.

Address correspondence to Megumi Shingu, R.N., M.S., Yoshioka Hospital, Yamagata, Japan 3-5-21 Higashihoncho, Tendo, Yamagata 994-0026, Japan. E-mail: m_gumi78@yahoo.co.jp

2666-061X/21512

https://doi.org/10.1016/j.asmr.2021.09.003

decreased to 70/48 mm Hg for several minutes, resulting in a persistent consciousness disorder and right hemiplegia after left shoulder arthroscopic surgery in the beach-chair position. In ARCR in the beach-chair position, it is dangerous to lower the blood pressure carelessly during the operation because it decreases cerebral blood flow and increases the risk of cerebral infarction.[3-9] No reports have investigated the relationship between blood pressure and visualization during ARCR.

The purposes of our study were to investigate the relationship between visualization and blood pressure during ARCR in the beach-chair position and to clarify the optimal blood pressure to maintain good visualization during surgery. We hypothesized that an intraoperative systolic pressure of 100 mm Hg would be safe, with good visualization.

Methods

This study was approved by our institute's ethics review committee of Yoshioka Hospital, Yamagata, Japan (YHTIB-2019-017). The subjects were 41 patients who underwent ARCR from January to April 2019. Patients were informed of this study in advance, and only patients who agreed to participate in this study were included. Patients were evaluated for current medical complications and their oral medications, but no exclusion criteria were applied in this study. All patients underwent general anesthesia by endotracheal intubation. After induction of anesthesia, an arterial line was inserted before the patient was placed in the beach-chair position, with continuous direct measurement of arterial pressure during the ARCR operation. After being placed in a beach-chair position at 60° from the supine position, an interscalene block was performed under ultrasonic guidance. The drug solution was 0.375% ropivacaine 10 mL + dexamethasone 3.3 mg. Patients who underwent noninvasive manipulation just before ARCR after induction of anesthesia were excluded from the study. Thirty-five of the 41 cases were included based on the study criteria. Their average age was 66 (43-84) years, with 23 male and 12 female patients. The right side was operated in 25 cases, and the left side was operated in 10 cases.

The patients' background characteristics, including American Society of Anesthesiologists (ASA) physical status classification (PS), basic diseases such as hypertension, diabetes mellitus, hyperlipidemia, presence or absence of cerebrovascular disease, presence or absence of oral anticoagulant use, and presence or absence of smoking history, were investigated.

In ARCR, the affected limb was fixed with a spider rim positioner (SPIDER Limb Positioner, Smith & Nephew, Oklahoma City, OK), and the glenohumeral joint was first observed from the posterior portal at the start of arthroscopy. The arthroscope was then inserted from the posterior portal into the subacromial space,

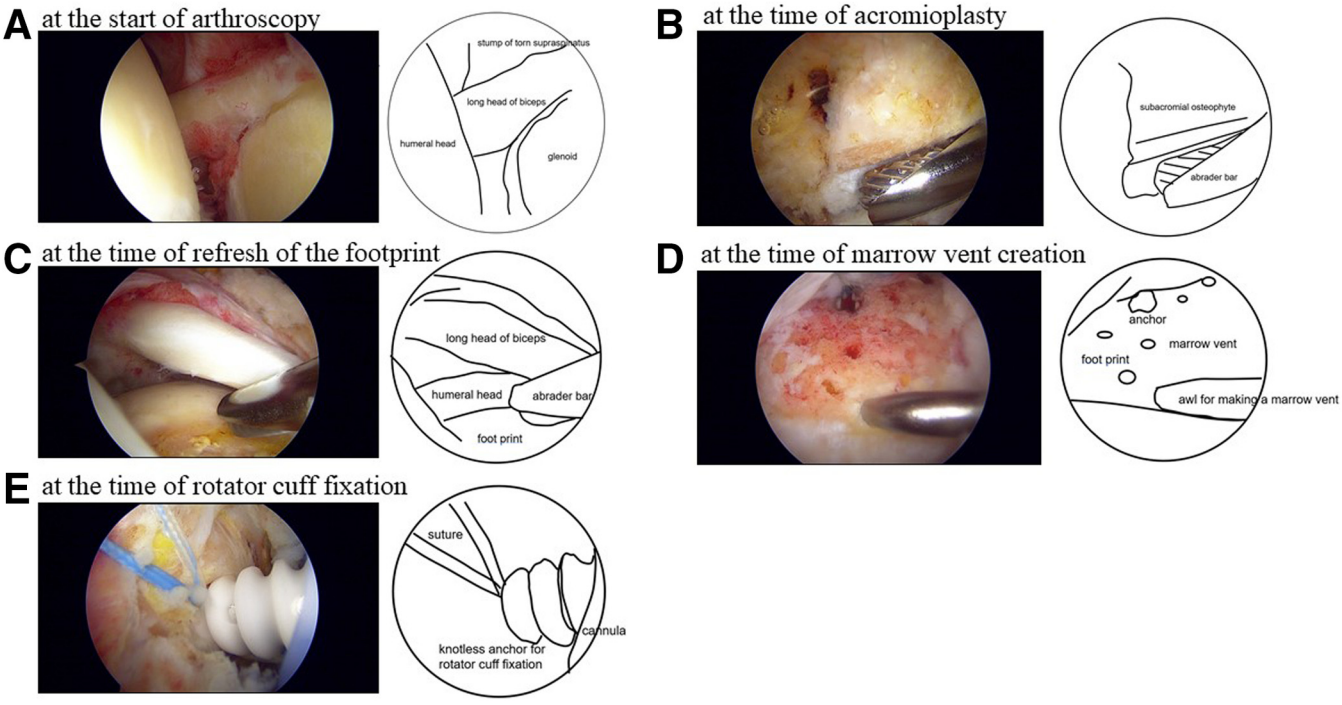

Fig 1. Visualization is evaluated at each stage in ARCR. (A) At the start of arthroscopy, the view from the posterior portal. (B) At the time of acromioplasty, the view from the posterior portal. (C) At the time of refresh of the footprint, the view from the posterior lateral portal. (D) At the time of marrow vent creation, the view from posterior lateral portal. (E) At the time of rotator cuff fixation, the view from the posterior lateral portal. (ARCR, arthroscopic rotator cuff repair.)

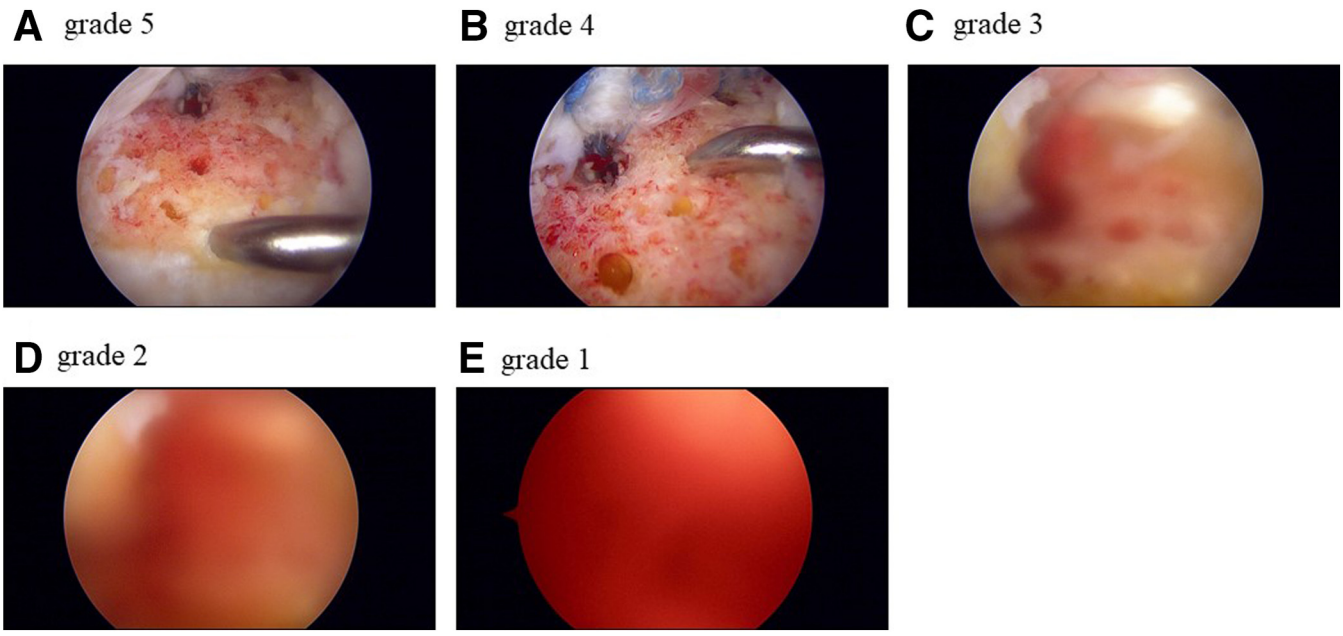

Fig 2. Visualization is rated on a scale of 1 to 5. (A) Grade 5, no bleeding and clear vision. (B) Grade 4, only a slight amount of bleeding, good visibility. (C) Grade 3, there is bleeding, but surgery can continue. (D) Grade 2, poor visualization due to bleeding, hemostasis is required, but no water or blood pressure treatment is required. (E) Grade 1, almost nothing can be seen due to massive bleeding, and surgery cannot be continued.

and acromioplasty was done. Subsequently, observation was performed from the posterior-lateral portal, footprint abrasion of the greater tuberosity of the humerus was performed to refresh the footprint, and medial suture anchors were inserted inside the footprint. After passing the suture thread of the medial suture anchor through the rotator cuff stump, bone marrow vents with a diameter of 1.5 mm were created in footprint marrow vent creation. Finally, when the rotator cuff stump was fixed in rotator cuff fixation, the suture thread passed to the stump of the rotator cuff was fixed to the far-lateral side of the greater tuberosity with a lateral suture anchor (Fig 1).

At the start of arthroscopy, at the time of acromioplasty, at the time of refresh of the footprint, at the time of marrow vent creation, and at the time of rotator cuff fixation, the same operator evaluated visualization on a scale of 1 to 5: grade 5, clear; grade 4, slight bleeding; grade 3, bleeding but operable; grade 2, poor visualization due to bleeding, hemostasis was required, but no water pressure or blood pressure treatment was required; and grade 1, almost nothing can be seen due to massive bleeding, and surgery could not be continued (Fig 2). For ARCR, arthroscopy was started from the posterior portal, and the anterior portal was created to probe the inside of the glenohumeral joint. In

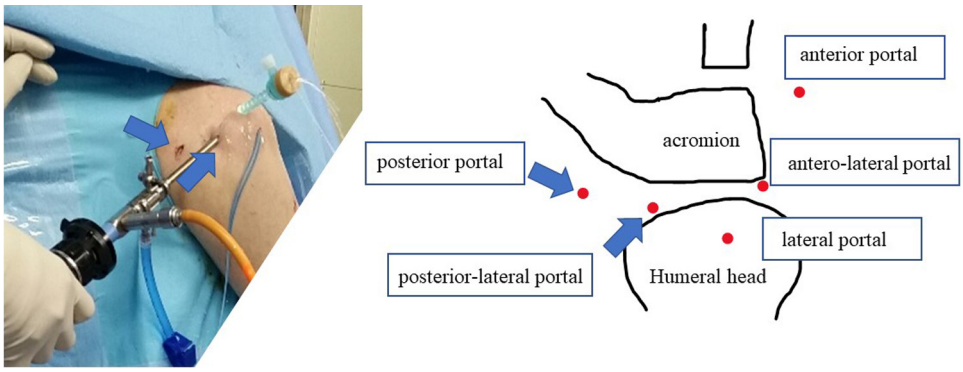

Fig 3. For ARCR, arthroscopy is started from the posterior portal, and the anterior portal is created to probe the inside of the glenohumeral joint. In the subacromial space, the posterolateral portal for viewing and the anterolateral portal for working are created. From the lateral portal, the torn rotator cuff is fixed to the outside of the greater tuberosity. Therefore, 5 portals are created. (ARCR, arthroscopic rotator cuff repair.)

Table 1. Visualization and Blood Pressure at Each Stage

Visualization	5		4		3		2		1		*P* Value	
	SBP (SD)	DBP (SD)	SBP (SD)	DBP (SD)	SBP (SD)	DBP (SD)	SBP (SD)	DBP (SD)	SBP (SD)	DBP (SD)	SBP (SD)	DBP (SD)
Start of arthroscopy	90 (14)	52 (9)	101 (20)	64 (10)							**.0257**	**.0057***
Acromioplasty	94 (9)	52 (7)	101 (1)	60 (14)	109 (7)	65 (7)	127 (−)	69 (−)	114 (−)	63 (−)	**.0023**	**.0399***
Refresh of the footprint	99 (12)	55 (8)	95 (3)	49 (6)	124 (11)	71 (1)					**.0201**	**.022***
Marrow vent creation	86 (14)	46 (3)	100 (8)	54 (7)	92 (35)	57 (8)	101 (32)	63 (11)	138 (−)	74 (−)	.4767	**.0194**
Rotator cuff fixation	86 (−)	44 (−)	102 (11)	55 (10)	104 (5)	59 (8)	108 (13)	64 (8)	116 (−)	65 (−)	.2652	.3277

DBP, diastolic blood pressure, SBP, systolic blood pressure; SD, standard deviation.
*, level of significance, P ≦ .05

the subacromial space, the posterolateral portal for viewing and the anterolateral portal for working were created. From the lateral portal, the torn rotator cuff was fixed to the outside of the greater tuberosity. Therefore, 5 portals were created (Fig 3). The irrigation fluid pressure during ARCR was maintained at 40 mm Hg with an arthroscopic pump (Smith & Nephew, Andover, MA) at a flow rate of 0.5 L/min, and 1 mg of epinephrine was co-injected into 3 L of perfusate (Arthromatic joint perfusion fluid; Baxter Limited, Tokyo, Japan) at the time of arthroscopic observation of the subacromial space. The operative time and the amount of irrigation fluid used also were investigated. The postoperative course was followed for 2 years to identify any postoperative complications.

Statistical analysis was performed with R, version 2.8.1 (The R Project for Statistical Computing, Vienna, Austria; open source). The relationship between the visualization grade and blood pressure during surgery was analyzed using one-way analysis of variance. The level of significance was set at .05. In the evaluation of visualization during surgery, the good visualization group included grades 5 and 4, and the poor visualization group included grades 3, 2, and 1; the cutoff value for the good visualization group was calculated from the receiver operating characteristic (ROC) curve.

In addition, reliability between examiners for the evaluation of visualization grade was investigated. During the ARCR operation, the assistant surgeon of the expert shoulder surgeon also performed the evaluation at the same time. Operator and assistant ratings were investigated by the intraclass correlation coefficient.

Results

In this series, there were 7 cases of ASA-PS class 1 and 28 cases of ASA-PS class 2, with an average class of 1.8. Systemic comorbidity included hypertension in 18 cases (51.4%), diabetes mellitus in 8 cases (22.9%), hyperlipidemia in 6 cases (17.1%), and cerebrovascular disease in 1 case (2.9%). Three patients (8.6%) were taking anticoagulants, 10 were smokers (28.6%), and 9 were nonsmokers with a smoking history (25.7%).

Table 1 shows the results of blood pressure measurement at each stage of ARCR. At the start of arthroscopy, all cases were visualization grades 5 and 4, and at the time of refresh of the footprint, they were only grades 5, 4, and 3. There were significant differences in the blood pressure at the time of the start of arthroscopy (P = .0257/.0057), at acromioplasty (P = .0023/.0399), and at refresh of the footprint on the greater tuberosity (P = .0201/.0272) between the visualization grade groups during ARCR, and they were related (Table 1). In addition, ROC analysis was performed with visualization grades 5 and 4 as the good visualization group and visualization grades 3, 2, and 1 as the poor visualization group. The cut-off value for

Table 2. Receiver Operating Characteristic Curve Values of Each Stage

	Cut-off Value		AUC	
Start of arthroscopy	SBP	DBP	SBP	DBP
Acromioplasty	104	60	0.95	0.91*
Refresh of the footprint	116	70	0.96	0.94*
Marrow vent creation	106	58	0.70	0.73*
Rotator cuff fixation	108	58	0.55	0.67

AUC, area under the curve; DBP, diastolic blood pressure, SBP, systolic blood pressure.
*, accuracy, This applies to both SBp and DBp;
0.5∼0.7, low accuracy;
0.7∼0.9, moderate accuracy;
0.9∼1.0, high accuracy.

the start of arthroscopy could not be evaluated, since all cases were only grades 5 and 4. The cut-off values for acromioplasty were 104 mm Hg for systolic blood pressure (SBP) and 60 mm Hg for diastolic blood pressure (DBP), and AUC values were 0.95 for SBP and 0.91 for DBP. At the refresh of the footprint, the cut-off values were 116 mm Hg for SBP and 70 mm Hg for DBP, and the AUC was 0.96 for SBP and 0.94 for DBP. At the time of marrow vent creation, the values were 106 mm Hg for SBP and 58 mm Hg for DBP, and the AUC values were 0.70 for SBP and 0.73 for DBP. The cut-off values at rotator cuff fixation were 108 mm Hg for SBP and 58 mm Hg for DBP, with AUC values of 0.55 for SBP and 0.67 for DBP (Table 2). None of the 35 patients included in this study had complications such as cerebral infarction, cerebral hemorrhage, or air embolism during and after surgery.

The intraclass correlation coefficient between the examiners for the visualization grade during ARCR was 0.76 at the start of arthroscopy, 0.68 at acromioplasty, 0.93 at refresh of the footprint, 0.88 at marrow vent creation, and 0.63 at rotator cuff fixation, and the total coefficient was 0.88 Thus, high reliability was obtained with this grading system (Table 3).

The median operative time for the good visualization group was 120.0 (84.0-148.0) minutes, and the median number of irrigation fluids used was 24 (15-31.5) L. In the poor visualization group, the median operative time was 133.5 (107.75-154.75) minutes, and a median of 30 (24-36) L of irrigation fluid were used ($P = .2111$, $P = .2147$). In addition, the median volume of irrigation fluid used per minute was 0.21 (0.17-0.25) L in the anticoagulant group and 0.22 (0.19-0.33) L in the no anticoagulant group ($P = .9623$).

Discussion

In the present study, blood pressure and visualization were significantly associated with the stages of starting arthroscopy, acromioplasty, and refresh of the footprint during ARCR. Good visualization is obtained by keeping blood pressure low during arthroscopic surgery. However, it has been reported that one case had intraoperative blood pressure maintained at 80-96/50-65 mm Hg, but the blood pressure decreased to 70/48 mm Hg for several minutes, which resulted in a prolonged consciousness disorder and right hemiplegia after left shoulder arthroscopic surgery in the beach-chair position. In addition, there have been reports of the risk of ischemic neuropathy due to decreased blood pressure and decreased local cerebral oxygen saturation, and convulsive seizures due to decreased cerebral blood flow during ARCR anesthesia management in the beach-chair position.[3,4,8-10] Therefore, in a patient who undergoes ARCR with some comorbid diseases, maintaining low blood pressure to obtain good visualization might also lead to an increased risk of cerebral infarction.

In the present study, the blood pressure that maintained good visualization during ARCR was calculated from the ROC curve, using 2 groups: the good visualization group, including clear visibility of grade 5 and extremely slight bleeding of grade 4; and the poor visualization group, with bleeding of grades 3, 2, and 1. The cut-off value of systolic blood pressure was 104 mm Hg at acromioplasty, 116 mm Hg at refresh of the footprint, 106 mm Hg at marrow vent creation, and 108 mm Hg at rotator cuff fixation. The AUC value was 0.9 or greater at acromioplasty and at refresh of the footprint. Thus, these cut-off values showed high credibility.

Based on the results of the present study, if the systolic blood pressure during ARCR were to be maintained at approximately 100 mm Hg, an operator could proceed with surgery without the stress due to poor visualization. Burkhart also mentioned that maintaining proper blood pressure during shoulder arthroscopic surgery could ensure good visualization with systolic blood pressure below 100 mm Hg.[11] Pohl et al. reported 4 cases of cerebral ischemia in the beach-chair position for shoulder surgery.[9] Their minimum systolic blood pressure was 80 mm Hg in 2 cases, 90 mm Hg in 1 case, and 50 mm Hg in 1 case. There have been no previous

Table 3. Interobserver Reliability for this Evaluation of Visualization

	ICC	Confidence level
Total	0.88	***
Start of arthroscopy	0.76	**
Acromioplasty	0.68	**
Refresh of the footprint	0.93	***
Marrow vent creation	0.88	***
Rotator cuff fixation	0.63	**

ICC, intraclass correlation coefficient.
*, moderate agreement.
***, almost a perfect match;
**, altitude match;

reports of complications with systolic blood pressure ≥100 mm Hg during ARCR surgery. From the results of the present study, the optimal systolic blood pressure with which the visualization of ARCR was good and patients could be ideally anesthetized was considered to be 100 mm Hg.

In the present study, the same operator evaluated the visualization grade to standardize the evaluation. The orthopaedic shoulder surgeon who was a surgical assistant evaluated the visualization grade at the same time to investigate the reliability between examiners using the intraclass correlation coefficient. A high reliability of about 0.7 or greater was obtained at the start of arthroscopy, acromioplasty, refresh of the footprint, and marrow vent creation. Overall, the reliability of the evaluation of this study was as high as 0.88, and this visualization grade might be useful.

There was no relationship between the visualization grade and the operative time or the amount of irrigation fluid used, although the operative time tended to be longer in the group with worse visibility. In addition, there was no difference in the amount of irrigation fluid used over time between subjects taking anticoagulants and those not taking anticoagulants, and this did not affect the visual assessment. Since the irrigation pressure and flow rate were maintained during each visual assessment, and the number of portals remained the same, it is likely that these had little effect on the visual assessment.

The ASA-PS classification is a general condition classification of the American Society of Anesthesiologists, and it is said that the evaluation of general condition before surgery and the prognosis after surgery are correlated. In the present study, 7 cases were in ASA-PS class 1, and the other 28 cases were in class 2, and these patients with mild systemic disease underwent ARCR. In the present study, hypertension was the most common disease, with 18 cases (51.4%), followed by diabetes mellitus. In addition, smokers, including those who had smoked, accounted for 54.3%, more than half, of the total. Arteriosclerosis due to hypertension, diabetes mellitus, and smoking not only increases the risk of intraoperative hypotension, but it may also be a risk factor for developing cerebral infarction. In addition to complications due to general anesthesia, postural change due to the beach-chair position during ARCR causes a temporary decrease in blood pressure and cerebral perfusion pressure, and it is associated with the risk of cerebral infarction. It can be said that surgery with systemic comorbidities is even more dangerous.[10] The subjects in this study were mostly male patients with an average age of 66 years, and most surgeries involved the right side. Therefore, they were similar to the epidemiological reports of the age and sex prevalence and sites of rotator cuff tears.

Limitations

There were some limitations in the present study. The number of subjects was small, at 35. Due to the small number of cases, the visual evaluation grade and blood pressure varied. However, 100 mm Hg was shown to be the standard blood pressure with good visualization and safety. Second, the visualization grade was based on a subjective evaluation by the operator. However, the inter-examiner reproducibility of this visual evaluation was high, at 0.88. Third, the analysis of blood pressures during the stage of ARCR was limited to the surgical operations on bones. Occasionally, arthroscopic surgery may not progress due to bleeding from various soft tissues. Fourth, there were no complications during ARCR in the present study. Therefore, it was impossible to measure the blood pressure that actually causes complications.

Conclusions

Good visualization during ARCR in the beach-chair position was significantly associated with blood pressure. An optimal blood pressure resulting in good visualization that would not cause excessive hypotension during ARCR surgery might be a systolic blood pressure of 100 mm Hg.

References

1. Skyhar MJ, Altchek DW, Warren RF, Wickiewicz TL, O'Brien SJ. Shoulder Arthroscopy with the patient in beach-chair position. *Arthroscopy* 1988;4:256-259.
2. Correa MC, Gonçalves LB, Andrade RP, Carvalho LH Jr. Beach chair position with instrumental distraction for arthroscopic and open shoulder surgeries. *J Shoulder Elbow Surg* 2008;17:226-230.
3. Shigetomi M, Kudo Y, Yamauchi N. Case of cerebral infarction during shoulder arthroscopy in the beach-chair position. *J Clin Anesth* 2017;37:181-185.
4. Friedman DJ, Parnes NZ, Zimmer Z, Higgins LD, Warner JJP. Prevalence of cerebrovascular events during surgery and association with patient position. *Orthopedics* 2009:32256-32260.
5. Frey K, Rehm M, Chappell D, et al. Preemptive volume therapy to prevent hemodynamic changes caused by the beach chair position: Hydroxyethyl starch 130/0.4 versus Ringer's acetate-a controlled randomized trial. *J Shoulder Elbow Surg* 2018;27:2129-2138.
6. Triplet JJ, Lonetta CM, Levy JC, Everding NG, Moor MA. Cerebral desaturation events in the beach chair position: Correlation of noninvasive blood pressure and estimated temporal mean arterial pressure. *J Shoulder Elbow Surg* 2015;24:133-137.
7. Kajita Y, Iwahori Y, Kato M, Sato K. The changes of cerebral circulation and electroencephalogram associated with beach chair position. *Shoulder Joint* 2009;3:547-549.
8. Mura N, Harada M, Yuki I. Hemiparalysis in the non-affected limb after the arthroscopic rotator cuff repair—two cases report. *Shoulder Joint* 2015;39:848-851.

9. Pohl A, Cullen DJ. Cerebral ischemia during shoulder surgery in the upright position, a case series. *J Clin Anesth* 2005;17:463-469.
10. Kokubo Y, Kayama T, Kondo R, Oki M, Takaoka S. The influence of general anesthesia on the brain in aged patients with previous ischemic cerebrovascular disease. *Surg Cereb Stroke* 2008;36:125-128.
11. Burkhart SS, Lo IK, Brady PC. *A cowboy's guide to advanced shoulder arthroscopy*. Philadelphia: Lippincott Williams & Wilkins, 2006.