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"Sclerotic Band" type of classification system and measurement of necrotic area for osteonecrosis of the femoral head

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Abstract

Background: Osteonecrosis of the femoral head is a common orthopedic disease. Based on years of clinical experience and significant imaging data, this study aimed to elucidate a new type of it, to help improve prognosis in young adults and provide a basis for hip preservation treatment.

Methods: From January 2014 to December 2016, a total of 211 patients undergoing hip preservation surgery for femoral head necrosis at our hospital were enrolled in this study. Coronal plane classification and cross-sectional area analysis were performed by nuclear magnetic resonance imaging (computed tomography optional) in cases meeting the inclusion criteria. Meanwhile, a new method of classification and calculating the necrotic area was proposed. The application simulation was conducted using sample cases. Additionally, treatment methods were recommended. We used our method to compare the outcome of the selected patients with the JIC classification so as to judge the advantages and disadvantages.

Results: The " pressure bone trabecular angle " of the femoral head was measured, and the "sclerotic band" (Zhang Ying) type of classification system and the "quartile" (Zhang Ying) method of measurement were used in 2 sample cases. After analysis, it is more accurate than JIC.

Conclusions: The "Sclerotic band" type of classification system and "quartile" methods are new methods to evaluate the stability of femoral head necrosis. They are convenient for clinical application and easily adopted.

Abbreviations: ASI = Average Stability Index, CT = optional computed tomography, DR = direct radiographs, FH = femoral head, HPS = hip-preserving surgery, MNAI = mean necrotic area index, MRI = nuclear magnetic resonance imaging, NOHP = non-operative hip preservation, ONFH = osteonecrosis of the femoral head, PBTA = pressure bone trabecular angle, QM = "quartile" method, SBTOCS = "sclerotic band" type of classification system, T1CP = T1-weighted image in the coronal position, T1CSP = T1-weighted image in the cross-sectional position, THA = total hip arthroplasty.

Keywords: classification, osteonecrosis of the femoral head, type

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1. Introduction

Osteonecrosis of the femoral head (ONFH) is a common disease in orthopedics,[1,2] and its treatment in young adults mainly focuses on hip-preserving surgery (HPS).[3–5] In these cases, total hip arthroplasty (THA) is not recommended.[3,6–8] Currently, there are several types of ONFH[4,6,7,9–12]; however, we found that these types have some shortcomings in predicting the prognosis of HPS. For example, the commonly used ACRO and JIC typing, although they have their own characteristics, but it may not be used to evaluate the mechanical conduction stability of the whole femoral head (FH).

Based on years of clinical experience and a large amount of imaging data, we propose a new type of classification system of ONFH to predict the prognosis of affected young adults better and provide the basis for HPS, when necessary. This study has been approved by the ethic review committee of our hospital.

The new type of ONFH proposed was named the "sclerotic band" (ZhangYing) type of classification system (SBTOCS). The method for measuring necrotic areas was named the "quartile" (ZhangYing) method (QM). Classification and cross-sectional area analysis were performed predominantly through the coronal plane using nuclear magnetic resonance imaging (MRI) (optional

Table 1

Number of patients with risk factors and the situation of men and women.

Risk factor	Obs	Age, y	Male	Female
Steroid	83	36.27 ± 8.01	51	32
Alcohol	63	35.17 ± 7.97	47	16
Trauma	21	33.19 ± 7.97	10	11
Idiopathic	44	36.25 ± 9.25	25	19
Total	211	35.63 ± 5.29	133	78

Table 2

Number of patients with risk factors and the situation of men and women.

Risk factor	Obs	Age, y	Male	Female
Steroid	31	37.06 ± 7.61	21	10
Alcohol	24	34.41 ± 7.27	17	7
Trauma	11	35.27 ± 7.68	6	5
Idiopathic	23	33.86 ± 9.34	13	10
Total	89	35.30 ± 7.99	57	32

computed tomography [CT] optional). This new SBTOCS and QM can be used to analyze the stability and calculate the average area of ONFH in general.

2. Materials and methods

A total of 211 patients who were diagnosed with ONFH in our hospital between January 2014 and December 2016 were included in this study (Table 1). The inclusion criteria were as follows: available 3.0T MRI results (may be including CT results but MRI was necessary) from our hospital at admission; available direct radiographs (DRs) obtained for pelvic and axial positions or frog position at the time of admission; and minimum follow-up of 2 years.

Three procedures were followed. First, the SBTOCS and QM were proposed through reading and analysis. Second, after MRI, the T1-weighted image in the coronal position (T1CP) was analyzed, and all image levels of the FH were evaluated and summarized to determine similarities and differences. Finally, after categorization of approximate forms and mechanical analysis the SBTOCS was designed. Third, the T1-weighted image in the cross-sectional position (T1CSP) was analyzed, and all image levels of the FH were evaluated, analyzed, and summarized to determine and formulate a simple and practical method for measuring the necrotic area of the FH. After the 2 methods, along with the application instructions, were finalized, application simulation was conducted in 2 examples.

We used our method to compare the outcome of the selected patients with the JIC classification so as to judge the advantages and disadvantages. The final efficacy was evaluated by Harris Score (which was good ≥80, medium ≥60, and bad <60).

3. Statistical analysis

Stata12 (USA) software was used for statistical description and chi square test was carried out for the success numbers of SBTOCS and QM VS JIC of prediction ($a = 0.05$).

4. Results

After screening a total of 89 patients (Table 2) with sufficient data on admission examination and follow-up were included in this study. Among them, 27 had left necrosis, 19 had right necrosis, and 43 had bilateral necrosis for a total of 132 hips (all stages are before ACRO IV). The T1CP of the FHs of the 132 hips showed 7 to 10 layers (mean: 7.72 layers). Ultimately, a total of 1019 coronal images were examined.

At the T1CP of the FH, we found an irregularly shaped sclerotic band and concluded that the distribution of this sclerotic band followed specific shapes that determined the stability of the mechanical conduction. The shapes were categorized as: "u" type, "x" type, "n" type, "s" type, and a combination of various forms ("mixed" type). Among them, 270 were of the u type, 154 of the x type, 123 of the n type, 135 of the s type, and 240 of the mixed type. In contrast, 97 showed no necrosis.

4.1. Mechanical analysis and principle of SBTOCS

The alignment directions of the tension and pressure trabecular bones could be clearly observed in the anteroposterior DR of the FH; because the hip is a weight-bearing joint, we indicated the direction of force conduction (Fig. 1). Moreover, the tension trabeculae of the FH had certain angles (angle γ: average angle between the lateral line of the pressure trabeculae and the vertical

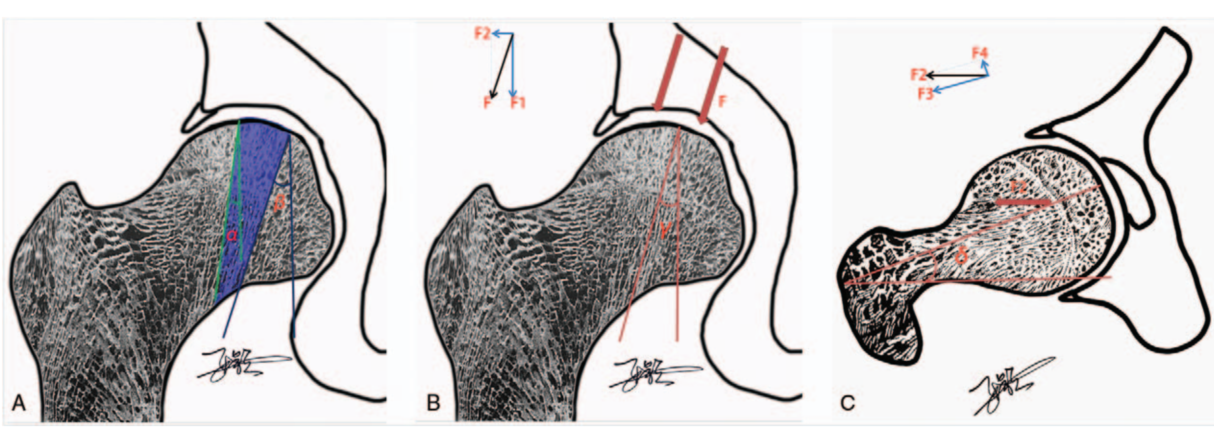

Figure 1. Angle of femoral head mechanical conduction.

Table 3

Measurement of angle.

Variable	Obs.	Mean	Std. dev.	95% Conf. interval	
Angle α	200	13.24	5.15	12.53	13.97
Angle β	200	18.77	7.00	17.79	19.75
Angle γ	200	16.01	6.01	15.23	16.79

95% Conf. interval = 95% confidence interval, Std. dev = standard deviation.

line – angle α and angle β) (Fig. 1A and B). As we could not find relevant reports on this angle, we measured the value of this angle and named it as the "pressure bone trabecular angle" (PBTA).

From the database of our hospital, We randomly selected 200 standard pelvis orthophoto DR of the patients (average age = 65.33 ± 7.94, male = 83, female = 117) with femoral neck fracture and used normal side to measure angle α and angle β (Table 3). The mean angle γ: 16.01 ± 6.01 degree (median, 14.99 degree). Therefore, there were horizontal tension and vertical downward pressures F2 and F3 (Fig. 1B) in the conduction of force direction of the FH. According to PBTA (14.99 degree), F3 was obviously much more powerful than F2, and F2 could be further analyzed from the transverse position of the FH.

From the transverse position of the FH, we could observe the dense arrangement of the tension trabeculae and the tension F2 that they bear. As the femoral neck had a certain inclination angle δ(12–15 degree), we found that a small amount of force was distributed to the lateral of the FH-F4 (Fig. 1C). Because the tension originated from the component force of the coronal position, leading to a smaller F4 force, we selected the coronal section for primary analyses.

In ONFH, the shape of the sclerotic band determines the stability of mechanical conduction. The following types were observed: u, x, n, x, s, and mixed types. As shown in Figure 2, mechanical conduction of the u, x, n, and s types was simulated to determine whether the structure was stable.

4.2. Schematic illustration of the SBTOCS

According to our mechanical analysis, the SBTOCS diagram was drawn. Although the schematic diagram was only drawn in the central coronal position, it represented different layers of sclerotic bands. Therefore, layer-by-layer analysis was needed in the application. In combination with the different examples, we marked the stable, moderately unstable, and unstable cases using green, yellow, and red circles, respectively, as follows. For the u type, there were 2 forms: single u type (A) and double u type (B). Each type was divided into 3 subtypes (ie, 1–3; Fig. 3A–F). Because the x and n types were unstable, subtypes

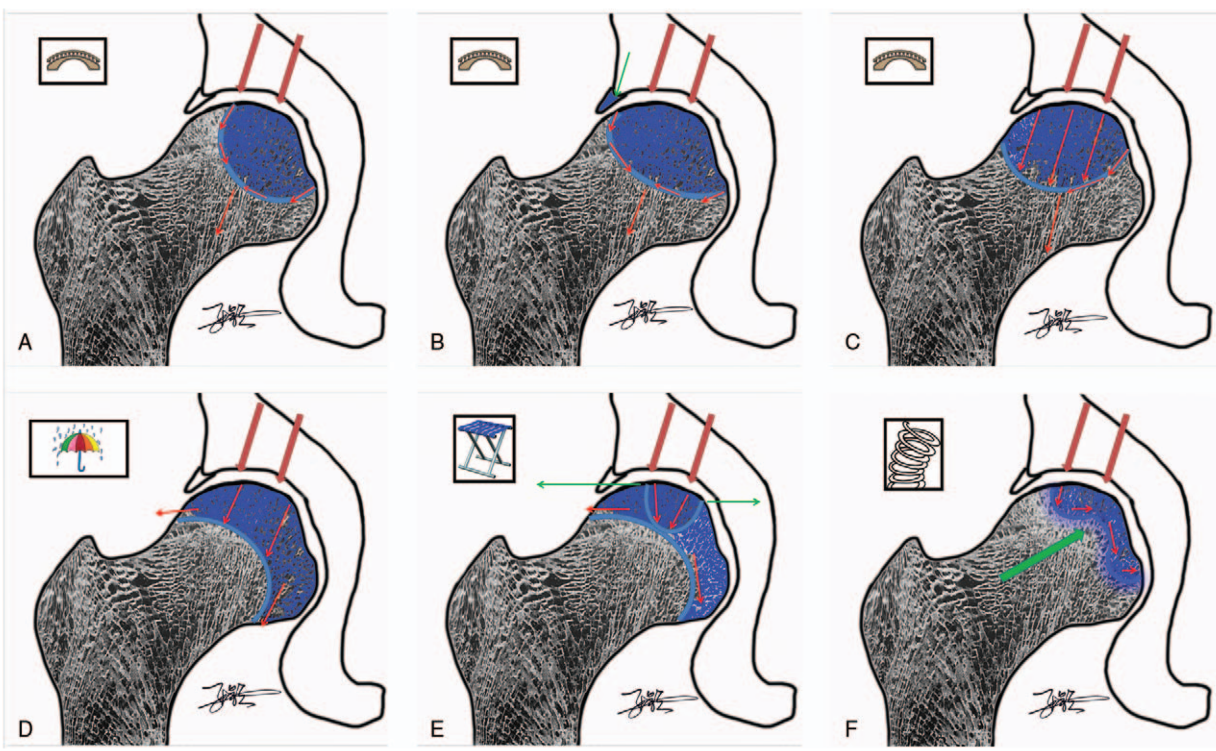

Figure 2. Different types of mechanical conduction force. (A–C) display a u shape, similar to the mechanical structure of an arch bridge. Arch force transmission is widely used in the bridge and construction industry, such as the Zhaozhou bridge in China. According to the relationship between the lateral arch and the acetabular margin, we divided it into lateral, marginal, and medial types. From the direction of force conduction, the medial type had stability (A), and the marginal type had moderate instability (B). Additionally, we found that some of these types had signal changes (eg, cystic changes, degeneration, and hardening) at the acetabular margin and labrum, which may be caused by the transmission of force (green arrow) from these areas. (C) This type was characterized by instability. The lateral stress did not transfer to the edge of the acetabulum, leading to lateral stress on the necrotic area and may cause collapse. (D) Shows the n type, also known as the anti-u type. This type was similar to falling water droplets from an umbrella in force conduction and has a spherical sliding property; thus, it was unstable. (E) Shows the x type, which was similar to folding a stool in force conduction. There was a large outward tension at the top of x (green arrow). When the femoral head was compressed, it tended to flatten; thus, it was unstable. (F) Shows the s type, which was similar to a spring in force conduction and has compressibility and elasticity; thus, it was also unstable. Some cases of this type formed a structure similar to a buffer belt in the axial position of the sclerotic band (green arrow).

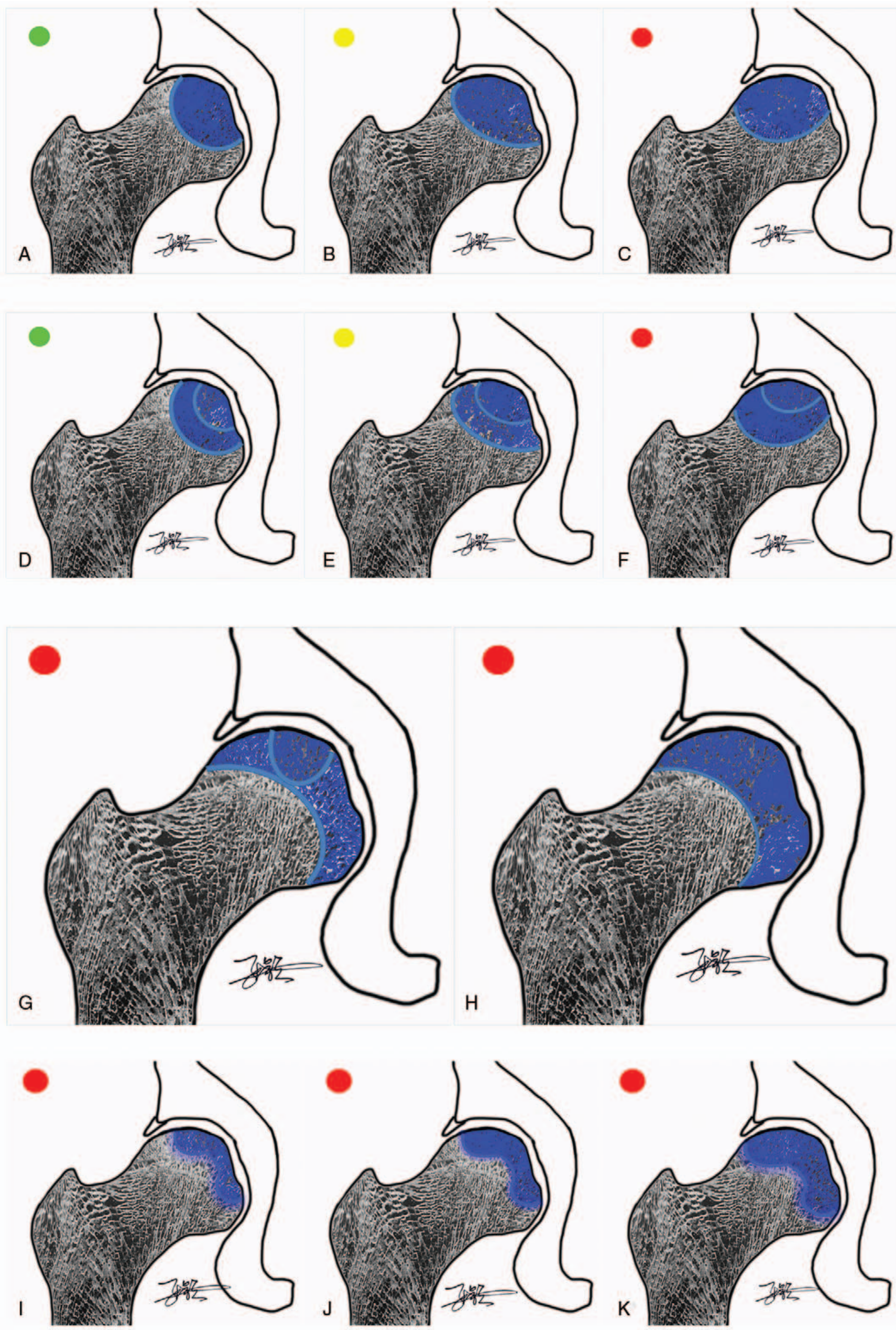

Figure 3. (A) Subtype ua1, (B) subtype ua2, and (C) subtype ua3, (D) Subtype ub1, (E) subtype ub2, and (F) subtype ub3; (G) x type and (H) n type; (I) s1 subtype, (J) s2 subtype, and k) s3 subtype.

Table 4

Average Stability Index.

Score	Degree of stability
>6	Stable
3–6	Moderately unstable
<3	Extremely unstable

The average score of Average Stability Index of 132 hips was 5.39 ± 2.18. According to the final follow-up results, good 27 (20.45%), medium 52 (39.39%), bad 53 (40.15%), we chose percentiles 20% and 60% as segmentation nodes. Percentile 20% is 3.12; percentile 60% is 6.16. According to the rounding-off method, we finally define integers 3 and 6 as split nodes.

Table 5

Mean Necrotic Area Index.

Score	Necrotic Area Index
<3	Small area of necrosis
3–5	Moderate area of necrosis
>5	Large area of necrosis

The average score of Mean Necrotic Area Index of 132 hips was 5.24 ± 2.13. According to the final follow-up results, good 27 (20.45%), medium 52 (39.39%), bad 53 (40.15%), we chose percentiles 20% and 60% as segmentation nodes. Percentile 20% is 3.39; percentile 60% is 5.07. According to the rounding-off method, we finally define integers 3 and 5 as split nodes.

were no longer employed for these classifications (Fig. 3G and H). Finally, the s type was divided into 3 subtypes (ie, 1–3). This type was similar to a spring in force conduction, with compressibility and elasticity, and was therefore unstable (Fig. 3I–K).

4.3. Application of SBTOCS

In applying the SBTOCS, all T1CP of the FH should be carefully interpreted, and each image involving the FH should be assigned a type and scored. If there is no necrosis in this layer, then it is considered stable, with a score of 10 points.

Notably, the type is not representative of all the induration patterns of necrotic sclerotic bands. In many cases, it will be a combination of multiple types. In this case, the largest type should be selected as the final type for evaluation. Scores of 10, 6, and 0 points indicate the stable, moderate unstable, and unstable type, respectively. The average score (Table 4) was defined as the sum of the scores of all levels divided by the number of levels, and was named the "Average Stability Index" (ASI).

4.4. Illustration of the QM

The T1CSP of the FH can effectively reflect the necrotic site and area. However, area calculation is difficult owing to the irregular morphology of necrotic areas. In this study, the FH in the T1CSP was divided into 4 parts according to the central axis of the head and neck of the femur (Fig. 4): a (blue), b (yellow), c (green), and d (red). Each part occupied 25% of the area (2.5 points), and when necrosis reached a corresponding area, the percentage was added.

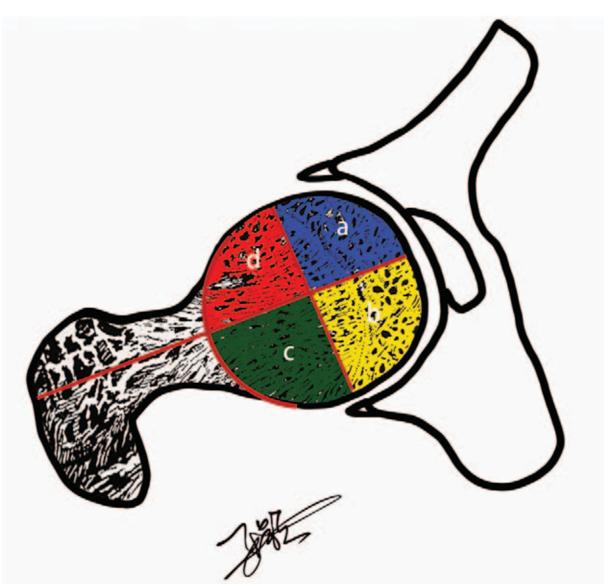

Figure 4. Schematic diagram of the femoral head necrotic area.

4.5. Application of the QM

In application, all T1CSP of the FH should be carefully interpreted, and each image involving the FH should be graded according to the area. If the necrosis reaches 2 areas, the score is 5 points. If it reaches 4 areas, the score is 10 points. If there is no necrosis at this level, the score is 0 points. The average score was defined as the sum of the scores at all levels divided by the number of levels. The evaluation criteria are shown in Table 5. The score was defined as the "Mean Necrotic Area Index" (MNAI).

4.6. Retrospective case analysis

4.6.1. Case 1

4.6.1.1. Before treatment. Case 1 is a 28-year-old man with alcohol-related necrosis and mild pain on the right side. In the earliest DR radiograph (Fig. 5A and B), necrosis was barely visible. An obvious sclerotic band could be observed on MRI in the T1CP (Fig. 5C–J). The ASI analysis showed that a total of 18 layers were scanned in the T1CP, showing 8 layers of FH. The final score of ASI was 0 + 0 + 0 + 6 + 0 + 6 + 6 + 10/8 = 3.5 points, which indicated moderate instability (Table 4).

Furthermore, the MNAI analysis showed that a total of 18 layers were scanned in the T1CSP, with 8 layers showing the FH. The necrotic areas at each layer could be identified and scored as follows (Fig. 5K–R): The final average score was 7.5 + 5 + 5 + 7.5 + 7.5 + 10 + 10 + 10/8 = 7.82 points (Table 6, Fig. 5). As this was >5 points, it indicated a large area of necrosis.

4.6.1.2. Initial treatment. Treatment included non-operative hip preservation (NOHP) with oral Chinese medicine (femoral head necrosis capsule).

4.6.1.3. After the initial treatment. After 9 months, the right hip pain had progressively worsened with recurrent symptoms. ONFH progressed with the FH slightly collapsed and irregular density changes (Fig. 6A and B). An increased necrotic area was observed on MRI (Fig. 6C–J).

The ASI analysis: with 8 layers showing the FH. The final ASI score was 0 + 0 + 0 + 6 + 0 + 0 + 0 + 0/8 = 0.75 points, which categorized it as extremely unstable (Table 4).

The MNAI analysis: with 8 layers showing the FH. The necrotic areas at each level were identified in the image. After analysis, the score for all layers was 10 points (Table 6, Fig. 6),

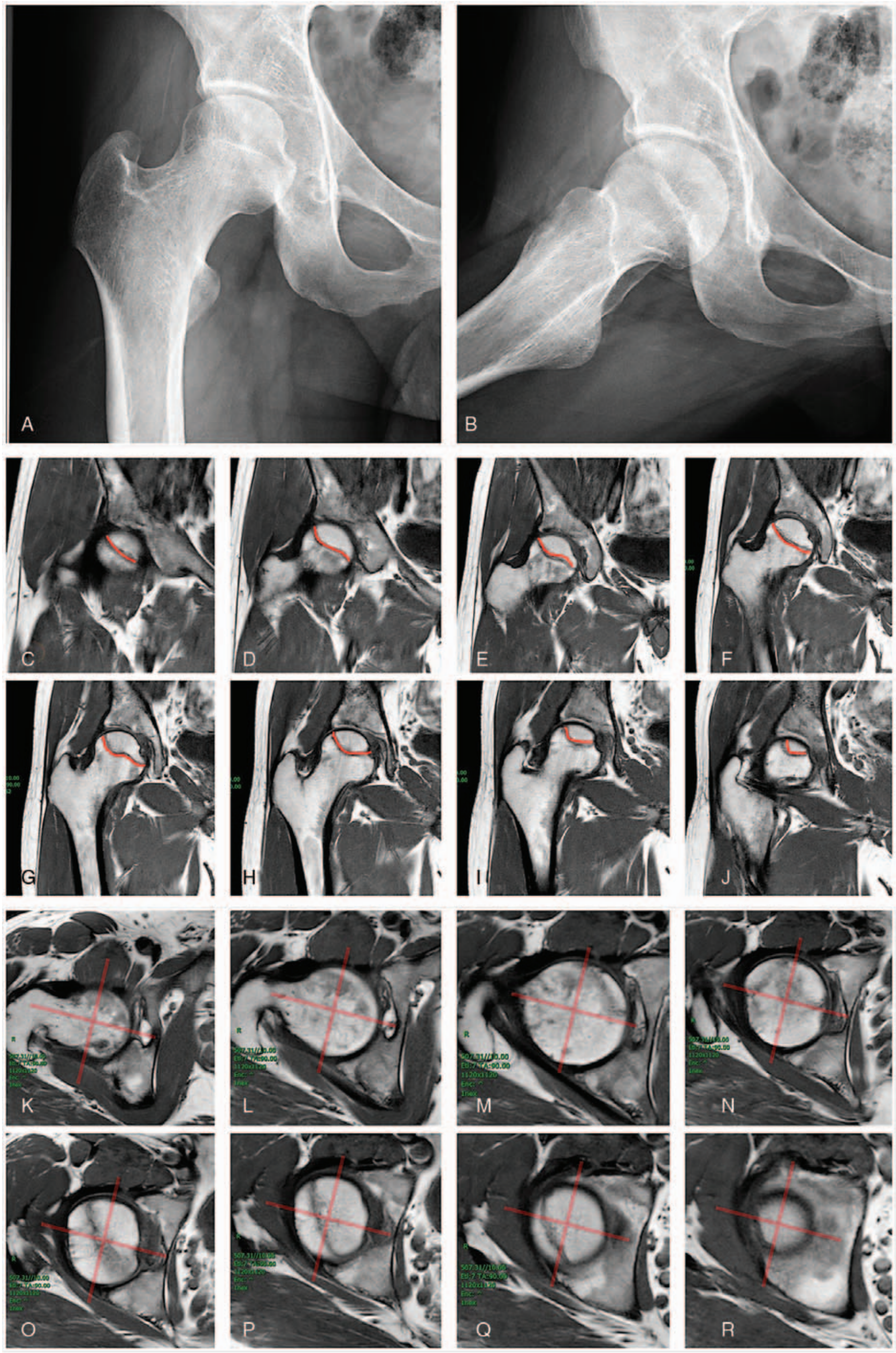

Figure 5. (A) October 2016 DR imaging of right position and (B) frog position. (C–J) October 2016 MRI imaging of coronal slices for different layers, the red line indicates the sclerotic band shape, ASI analysis: the c layer was ua3 type; d layer, s2 type; e layer, s2 type; f layer, ua2 type; g layer, s2 type; h layer, ua2 type; i layer, ua2 type; and j layer, ua1 type. (K–R) October 2016 MRI imaging of transverse section slices, the red cross-lines indicate the central cross of the femoral head.

Table 6

Scores of necrotic area at different figures.

Figure 5		Figure 6		Figure 7		Figure 9	
Layer	Score	Layer	Score	Layer	Score	Layer	Score
k	7.5	k	10	M	0	i	0
l	5	l	10	N	0	j	0
m	5	m	10	O	0	k	0
n	7.5	n	10	P	5	l	2.5
o	7.5	o	10	Q	5	m	5
p	10	p	10	R	7.5	n	10
q	10	q	10	S	10	o	10
r	10	r	10	T	10	p	10

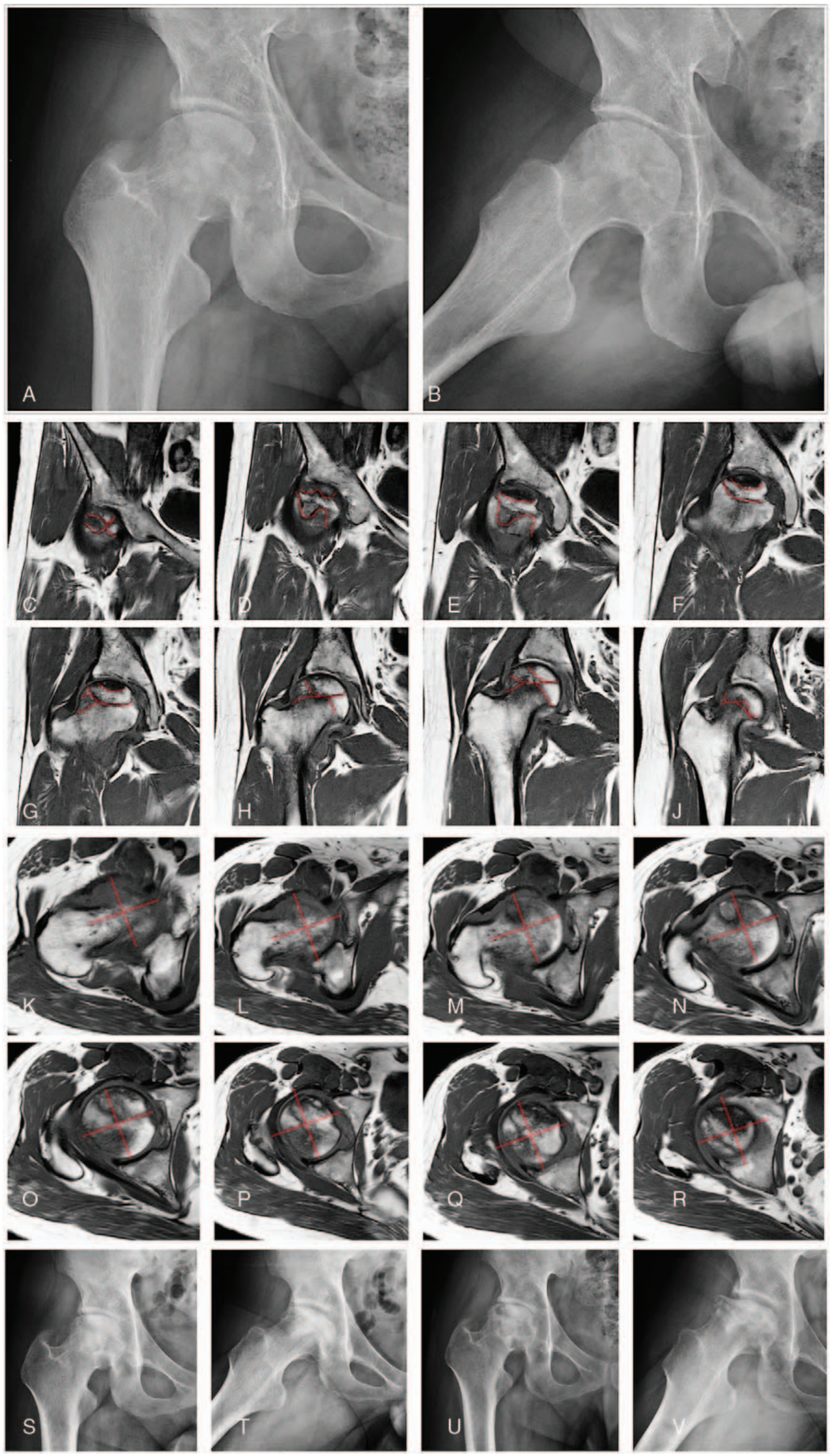

Figure 6. (A) July 2017 DR imaging of right position and (B) frog position. (C–J) July 2017 MRI imaging of coronal slices for different layers, the red line indicates the sclerotic band shape. The layer c was x type; d layer, s3 type (this type was s3 type including ua3 type, whereas ua3 type included s2 type. According to the application instructions, it was identified as an s3 type; e layer, s3 type (this type was s3 type including ub2 type); f layer, ub2 type; g layer, n type (this type was n type including s3 type, while s3 type including ub2 type); h layer, x type; i layer, x type (this type was x type including ua1 type); j layer, n type (this type was n type including s3 type). (K–R) July 2017 MRI imaging of transverse section slices, the red cross-lines indicate the central cross of the femoral head. (S) January 2018 DR imaging of right position and (T) frog position; (U) July 2018 DR imaging of right position and (V) frog position.

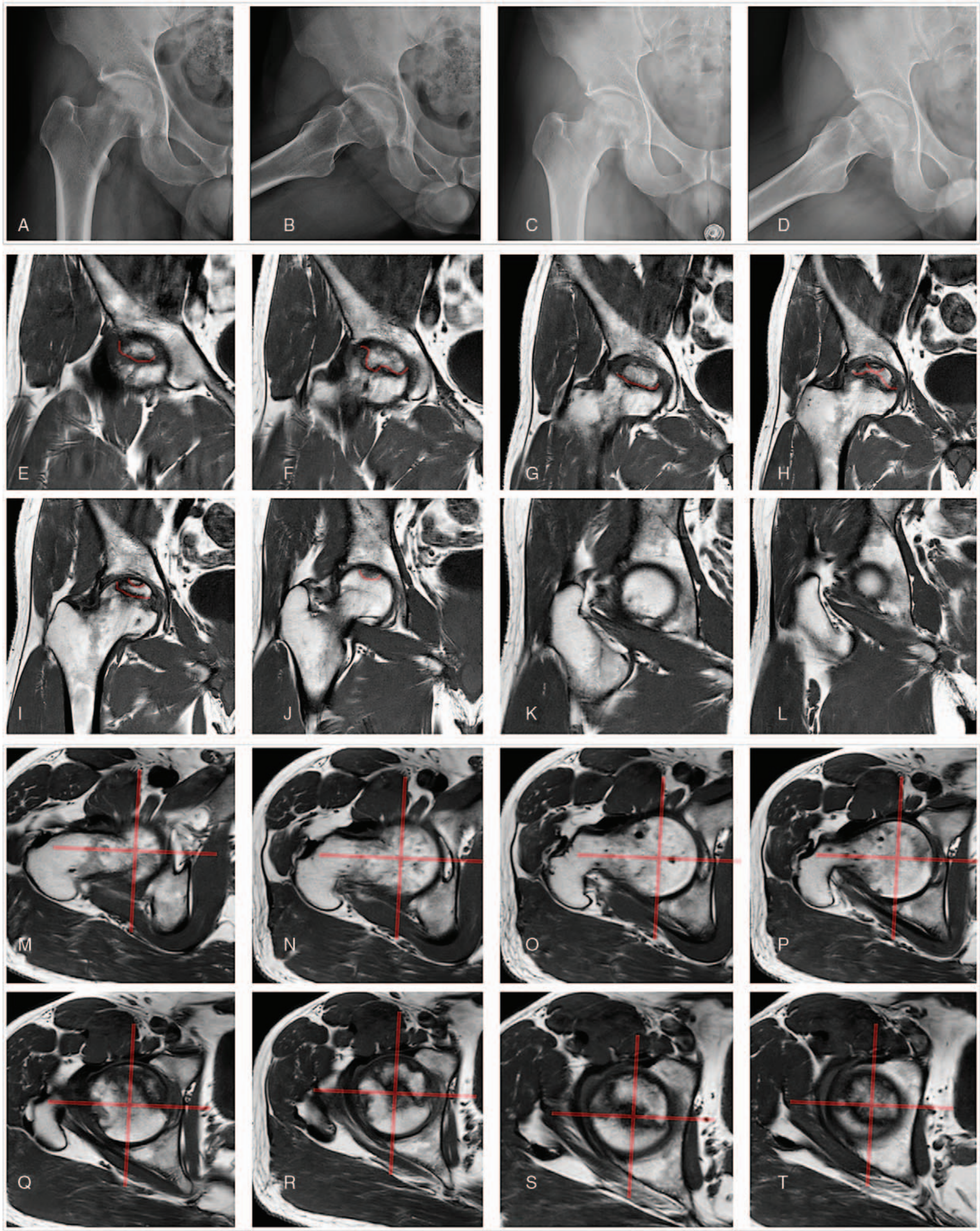

Figure 7. (A) December 2015 DR imaging of right position and (B) frog position. (C) March 2016 DR imaging of right position and (D) frog position. (E–L) March 2016 MRI imaging of coronal slices for different layers, the red line indicates the sclerotic band shape, e layer was ua2 type; f layer, S1 type; g layer, ua2 type; h layer, s2 type; i layer, ub1 type; j layer, ua1 type; and the k and l layers had no necrosis. (M–T) March 2016 MRI imaging of transverse section slices, the red crosslines indicates the central cross of the femoral head.

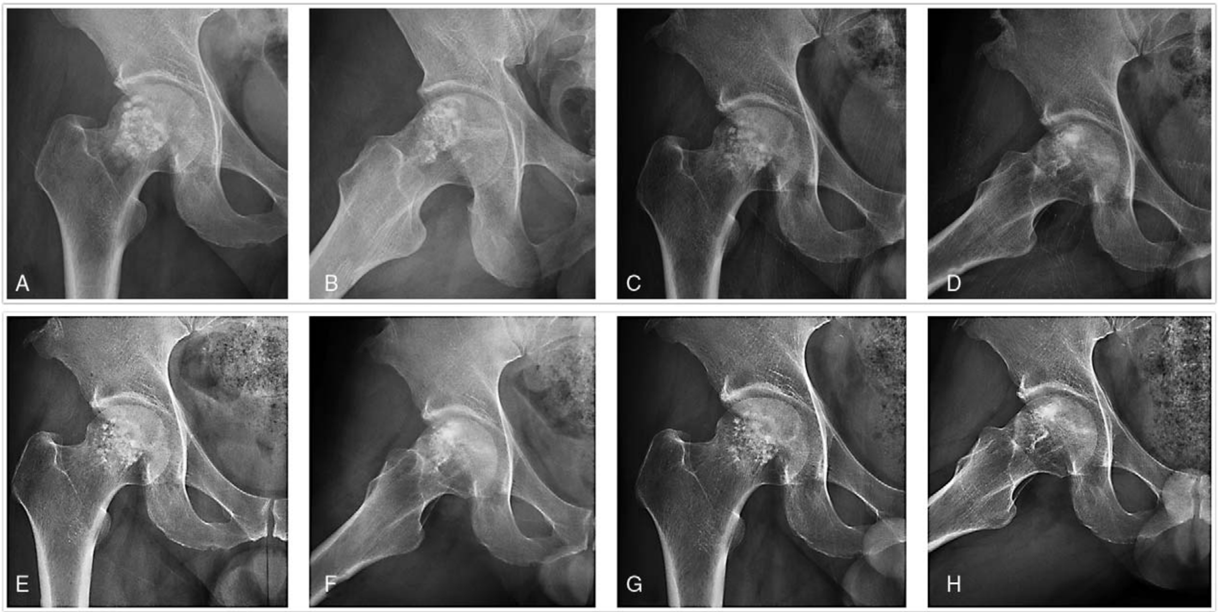

Figure 8. (A) March 2016 postoperative DR imaging of right position and (B) frog position; (C) September 2016 DR imaging of right position and (D) frog position. (E) February 2017 DR imaging of right position and (F) frog position; (G) September 2017 postoperative DR imaging of right position and (H) frog position.

with an average score of 10 points (total head necrosis), indicating a large area of necrosis (Table 5).

4.6.1.4. Second treatment. HPS in July 2017.

4.6.1.5. After the second treatment. After 3 months, weight-bearing was permitted. After 6 months (January 2018), the patient's right hip movement was severely restricted, and pain increased (Fig. 6S, T). At 1-year follow-up (July 2018), the FH was seriously collapsed and deformed; osteoarthritis was found, suggesting failed hip preservation therapy (Fig. 6U, V).

4.6.2. Case 2

4.6.2.1. Before treatment. A 38-year-old man had hormonal ONFH on the right side. ONFH complicated with mild discomfort of hip at December 2015. Overall, 4 months (March 2016) after the patient noted mild discomfort, mild pain occurred in his right hip. He also noted claudication. The earliest DR radiographs showed sclerosis and cystic changes (Fig. 7A–D). The sclerotic band was observed on T1CP, and the FH had a good shape (Fig. 7E–I).

ASI analysis: with 8 layers showing the FH. The final ASI score was $6+0+6+0+10+10+10+10/8=6.5$ points, which indicated stability (Table 4).

MNAI visible at 8 MRI layers indicated FH. The necrotic areas in each layer could be identified (Fig. 7M–T). There was no necrosis in layers m-o. The final average score was $5+5+7.5+10+10/8=4.69$ points (Table 6, Fig. 7), which indicated a moderate area of necrosis (Table 5).

4.6.2.2. Treatment. HPS in March 2016(Fig. 8A and B).

4.6.2.3. After treatment. Based on the DR radiographs obtained 6 months, 1 year, and 1.5 years after HPS, there was no obvious change in the FH shape (Fig. 8C–H). The graft shadow was visible in the FH, and the ilium was absent.

ASI analysis: repeat MRI was conducted in September 2017 (Fig. 9A–H). The final ASI score was $0+6+0+10+10+10+10+10/8=7$ points, indicating stability (Table 4).

The MNAI analysis: with 8 layers showing the FH. There was no necrosis in layers a-c (Although there was a hardening shadow left by the bone grafting in the c and d layers, it could not be considered necrosis.) The final average score was $2.5+5+10+10+10/8=4.69$ points (Table 6, Fig. 9).

At the final follow-up (3 years and 3months after HPS), the function of the right hip joint was good, and the hip joint was retained. The patient still undergoes follow-up (Fig. 9S, T).

4.7. SBTOCS and QM versus JIC

Of the 132 hips, 27 had NOHP and 105 HPS (operated on the same way). The results of STBOBS and QM (Table 7) versus JIC (Table 8): Pearson $\chi^2=4.8068$, $P=.028$ (<.05). It shows that our method is more accurate (Table 9).

5. Discussion

ONFH remains a health care problem mainly in young adults (age: 30–50 years).[1,13] If it is not treated, it eventually leads to FH collapse,[4,14,15] osteoarthritis, and disability, requiring THA.[7,16,17] In early ONFH, insurable value of the hip treatment is not recommended for THA.[1,7,11] Especially for young patients, preserving the hip is an important therapeutic goal.[1,2,8] HPS is achieved through one of the following approaches so as to prolong the use time of the hip: reducing joint capsule pressure; removing necrotic tissue; using a tantalum rod or autologous bone to support the FH and prevent its collapse; increasing blood

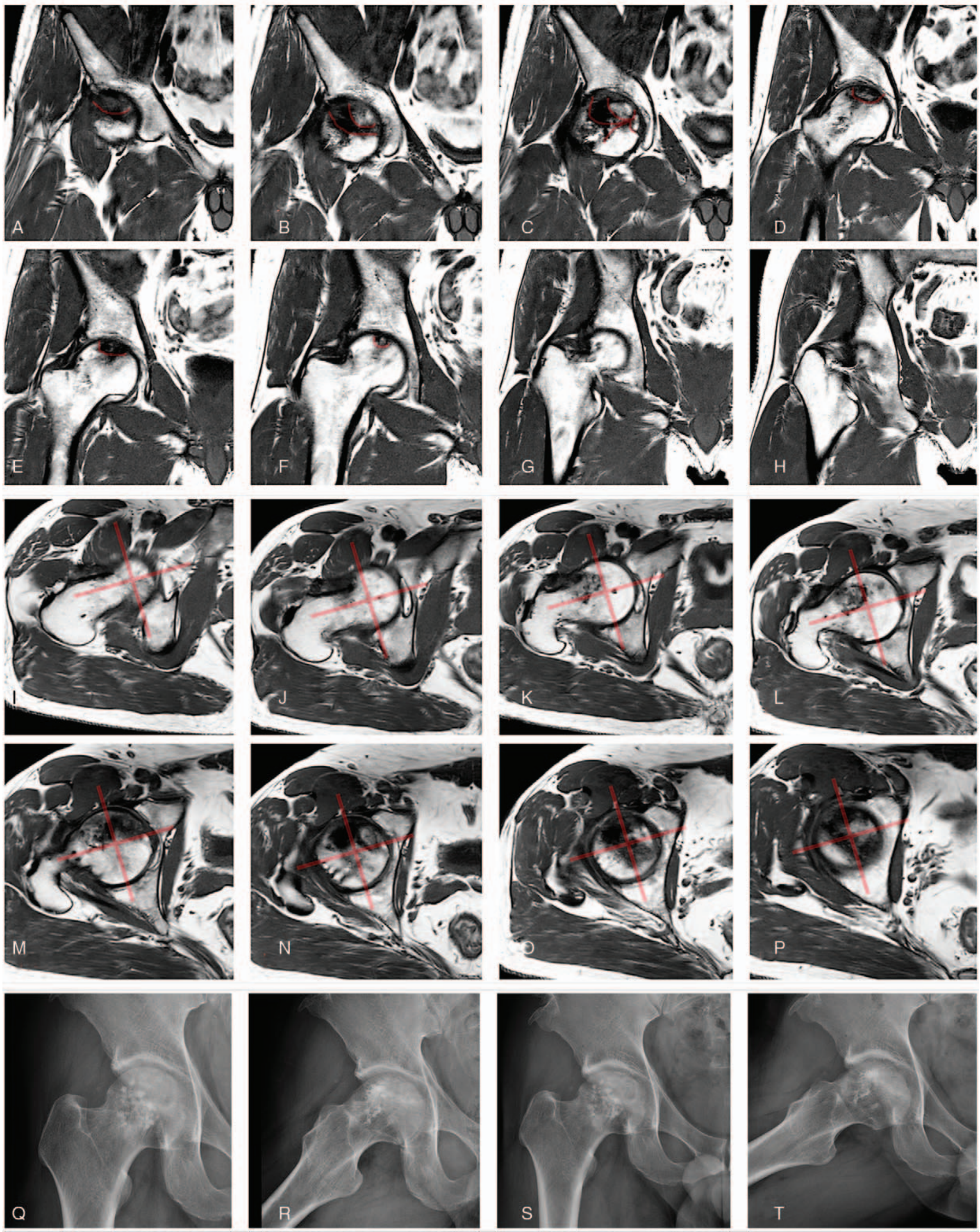

Figure 9. (A–H) September 2017 MRI imaging of coronal slices for different layers, the red line indicates the sclerotic band shape, the a layer was ua3 type; the b layer, ub2 type; c layer, x type (this type was x type, including ub2 type); d-f layers, ub1 types; the g and h layers had no necrosis. (I–P) September 2017 MRI imaging of transverse section slices, the red cross-lines indicate the central cross of the femoral head. (Q) December 2018 DR imaging of right position and (R) frog position. (S) March 2019 final follow-up DR imaging of right position and (T) frog position.

Table 7

Prediction results of SBTOCS and QM.

ASI	MNAI	Prediction outcome	Hips	Current results			Success number
				Good	Medium	Bad	
Stable	Small	Good	5	4	1	0	4
	Moderate	Good	16	12	2	2	12
	Large	Medium	9	2	6	1	6
Moderately unstable	Small	Medium	13	2	10	1	10
	Moderate	Medium	14	5	7	2	7
	Large	Medium	19	1	15	3	15
Extremely unstable	Small	Medium	12	1	8	3	8
	Moderate	Bad	21	0	3	18	18
	Large	Bad	23	0	0	23	23
Total		/	132	27	52	53	103

ASI = Average Stability Index, MNAI = mean necrotic area index, QM = quartile method, SBTOCS = “sclerotic band” type of classification system.

Table 8

Prediction results of JIC.

JIC	Prediction outcome	Hips	Current results			Success number
			Good	Medium	Bad	
A	Good	8	7	1	0	7
B	Good	25	17	7	1	17
C-1	Medium	52	3	30	19	30
C-2	Bad	47	0	14	33	33
Total	/	132	27	52	53	87

supply to the FH; and bone repair mechanism necrosis regional organizations prevent further FH collapse and necrosis.[2,3,7]

ONFH treatment depends mainly on its stage and the surgeon’s clinical discretion.[1] It is focused on improving symptoms and delaying THA.[2] Hence, the stability of ONFH is very important.[4] Based on study findings and years of clinical experience, we proposed a new SBTOCS and it was described for easy comparison. However, the forms listed herein are not representative of all the sclerotic band forms, and there are many cases where the sclerotic band is a combination of multiple forms (hybrid). Additionally, we proposed a detailed description of the method’s application in 2 examples and finalized the concept of the ASI. Currently, there is a lack of a simple and effective method for measuring the necrotic area owing to the sphericity of the FH and irregularity of the sclerotic band. Therefore, we proposed the concept of QM and MNAI.

In many previous descriptors, FH collapse is an important evaluation index.[1,2] However, collapse is not mentioned in our type because it is caused by instability itself. Therefore, the type detailed here intends to transfer collapse as an evaluation index to its source—mechanical instability. If a collapsed case is stable after analysis, NOHP can be continued. If a patient suffers from massive hip instability and there is no collapse of the FH, HPS should be performed promptly. Nevertheless, the key to treatment is improving the stability of the FH.

In these cases, hip preservation therapy failed in case 1. We provided detailed explanations and analyses based on ASI and MNAI, suggesting that early HPS for large area of necrosis and moderately unstable necrosis may have different outcomes. In contrast, hip preservation in case 2 was successful, suggesting that a moderate area of necrosis with stability has a good prognosis.

The innovations of this study are as follows. First, a new method “SBTOCS” for ONFH was proposed. Second, a new area measurement method “QM” for ONFH was proposed. Finally, the angle PBTA was measured. Conversely, its limitations are as follows. The sample size was small; thus, a larger sample size is needed to confirm our findings for clinical application.

Any classification and measurement method is not perfect, and needs a larger sample size to improve. This will permit more accurate clinical application. Owing to the diversity of HPS, every doctor has a different approach. Valuable opinion sharing and discussion are needed to improve these two methods.

Table 9

SBTOCS and QM versus JIC.

Type	Hips	Success number	Failure number	Pearson χ^2	P
SBTOCS and QM	132	103	29	4.8068	.028
JIC	132	87	45		

ASI = Average Stability Index, MNAI = mean necrotic area index, QM = quartile method, SBTOCS = “sclerotic band” type of classification system.

In summary, these 2 methods provide new strategies to evaluate the stability of ONFH. They are convenient for clinical application and easily adopted.

Author contributions

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