Observational Study

Medicine

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Acute hemicranial pain accompanied with a pearl and string type dissection of intracranial vertebral artery

Consideration for the time when to finish the medical observation

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Abstract

The International Classification of Headache Disorder (ICHD) clearly guides the suspicion of intracranial vertebral artery dissection (ICVAD) in headache patients, but guidelines on how observational or imaging studies should be performed to detect dangerous progression early are unclear. Fifty-six cases with pearl and string type intracranial vertebral artery dissection were divided into 3 groups: 39 in the headache group, 6 in the infarction group, and 11 in the hemorrhagic group. Clinical and angiographic data were analyzed and compared. Most headaches resolved within 2 weeks and did not exceed 8 weeks. Of the 33 patients (84.6%) who underwent continuous follow-up imaging, 18 (54.5%) returned to normal, but 3 (9%) had deteriorated. All the patients survived without subsequent bleeding or infarction. Image changes started before 3rd month and ended after 6 to 7 months. In acute ICVADs, image changes occur at the same time as the headache resolves and continue for several months after the headache has subsided. Since the dissection is likely to worsen even after the headache disappears, the image changes continue over several months, and prediction of rupture of unruptured ICVAD is unpredictable, it is desirable to conduct continuous imaging studies regularly after the initiation of dissection until stabilization is confirmed.

Abbreviations: CTA = computed tomography angiography, ICVAD = intracranial vertebral artery dissection, MRA = magnetic resonance angiography, SAH = subarachnoid hemorrhage.

Keywords: dissection, headache, vertebral artery

1. Introduction

Spontaneous intracranial vertebral artery dissections (ICVADs) usually have a benign, self-recovering nature when detected without hemorrhage or infarction.[1–3] In contrast, ICVADs, which initially cause bleeding or infarction can be aggressive and often fatal.[4–6] In general, the natural course and clinical outcome of ICVAD is highly dependent on the initial presentation pattern.[1,3] Therefore, an unruptured dissection is usually managed conservatively, whereas a ruptured ICVAD is treated immediately.[7] This type of treatment trend requires a prerequisite that an unruptured dissection with only a headache at the time of presentation should not cause any subsequent bleeding or infarction. However, there are reports supporting evidence that conservatively managed ICVADs have a potential risk of delayed hemorrhage or infarction.[8,9] Currently, owing to advances in endovascular treatment technology, more unruptured ICVADs are being treated prophylactically because of uncertainties about prognosis.[7,10] In order to prevent subsequent bleeding that may occur due to the progression of dissection, ICVADs which are thought to be prone to bleeding should be recognized early. The International Classification of Headache Disorder (ICHD) clearly guides the suspicion of intracranial artery dissection in headache patients, and although studies on angiographic properties related to spontaneous healing or bleeding are well published, guidelines on how observational or imaging studies should be performed to detect dangerous progression early are unclear.[11–13]

The angiographic pearl and string signs are features that both ruptured and unruptured ICVADs have in common when they present only with headache. Headache can be a warning sign that rupture is imminent, but neither pain intensity nor angiographic characteristics are reliable predictors of

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dissection progression.[9,14,15] Headache relief is not necessarily a sign of a cure; therefore, if pearl and string type ICVADs are found in patients with acute headache, a decision should be made whether to treat it immediately or simply to perform follow-up imaging studies until stabilization of the dissection is confirmed.

In this study, we observed headache progression and imaging changes during the follow-up period, determined how long a non-stroke type dissection should be followed by imaging studies, and suggested when to consider treatment options.

2. Materials and methods

This retrospective was approved by the Institutional Review Board of the Konkuk University Medical Center, Seoul, Republic of Korea (KUMC 2021-07-063). Radiologists' reports were searched for computed tomography angiography (CTA) or magnetic resonance angiography (MRA) images covering the head and neck regions performed from 2005 to 2018 to find the keywords "dissection" and "vertebral artery" in the conclusion sections. Then, each image was analyzed by a neurosurgeon, neurologist, and neuroradiologist to find the pearl and string sign, which shows alternating combinations of dilatation and stenosis. Some cases were difficult to distinguish from mimic conditions such as reversible cerebral vasoconstriction syndrome or atherosclerotic stenosis and dilatation. Therefore, cases were enrolled only when all 3 reviewers agreed with each other's interpretation. After the initial diagnosis, all radiographic images taken afterward were analyzed to determine when the anatomical changes of the dissection appeared and when it stopped. It was concluded that improvement was achieved when the affected vertebral artery segment was completely restored to normal or remained smoothly dilated without stenosis, and it was considered worsened when it became stenotic, tapered, or occluded.

Clinically we divided the cases into 3 subgroups; hemorrhagic group with subarachnoid hemorrhage (SAH); infarct group with acute medullary or cerebellar infarction; the remaining cases were classified into the headache group. Since the characteristics of headaches are diverse and the description methods differ from person to person, the characteristics of the patient's headaches were simply analyzed according to their location and severity. The analysis of pain location included the hemi-cranial and occipito-nuchal regions, and the consistency with dissection location. Headache severity included abruptness and intensity assessed using a visual analog scale (VAS). To determine the duration and interval of imaging studies, the duration from the onset to the end of the headache was compared with the same duration of image changes.

One-way analysis of variance (ANOVA) was used to analyze differences in headache characteristics, such as intensity, location, and accompanying symptoms, between the 3 groups. Differences between the 2 groups (headache and infarction) of time-dependent factors, such as onset/relief of headache and onset/stop of angiographic changes, were analyzed using

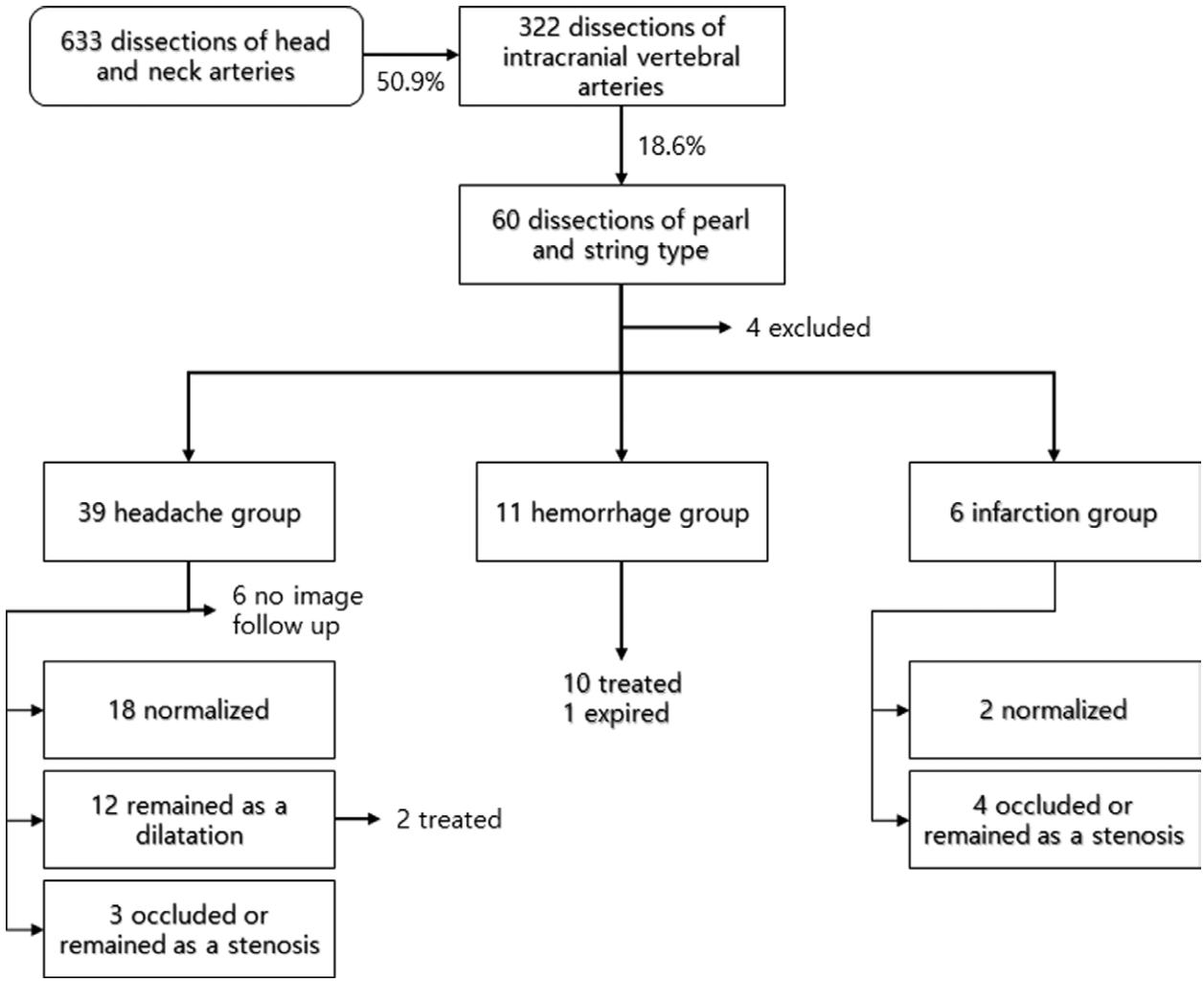

Figure 1. Flow chart showing the case selection procedure and follow-up results.

an independent 2-sample t-test and visualized with a Kaplan–Meier curve (IBM SPSS Statistics for Windows, Version 20. IBM Corp., Armonk).

3. Results

We identified 633 patients with dissection of the arterial system of the head and neck. Of these, 322 (50.9% of all head and neck dissection cases) had IVADs, showing a heterogeneous disease spectrum. Typical pearl and string type dissections were found in 60 patients (18.6% of IVADs), and medical record analysis was performed. Unfortunately, 4 patients did not appear on the next appointment and had to be excluded due to insufficient medical records. Finally, the 56 patients were divided into 3 groups: 39 in the headache group, 6 in the infarction group, and 11 in the hemorrhagic group (Fig. 1).

3.1. Clinical and anatomical results

In the headache group, all headaches were relieved within 2 months (5–52 days, mean 14 days), and all patients survived long enough (37–5828 days, median 1498 days) without subsequent bleeding or infarction. Of the 33 patients (84.6%) who underwent continuous follow-up imaging, 18 (54.5%) returned to normal, but 3 (9%) had deteriorated into irregularly narrowed or occluded lesions. The rest showed partial improvement due to incomplete recovery of the dilated segment. Ten cases remained fusiform dilatation, and 2 cases transformed into a more saccular form and were treated using the endovascular method (Table 1).

The duration of headache in the infarction group was shorter than that in the headache group (2–13, mean 5.5 days vs 5–52 days, mean 14 days, $P = .033$). However, anatomical improvement was less than that in the headache group. Two returned to normal (33.3%), and 4 deteriorated into stenosis or obstruction (66.7%). All patients survived long enough (51–3800 days, median 1531 days), and none of them experienced recurrent infarction or bleeding. In the hemorrhage group, 1 patient did not receive treatment due to a grave condition at the time of admission, but all others were successfully treated using the endovascular method.

3.2. Presentation patterns and characteristics of the headaches

Regardless of group, most headaches occurred during daily activities. Sometimes, headaches are accompanied by dizziness and nausea. Nausea may suggest increased intracranial pressure

Table 1

Summary of clinical and angiographical analysis.

	Headache	Hemorrhage	Infarction	*P*
Cases	39	11	6	
Age, mean (range)	47.8 (34–67)	46.8 (28–64)	49.5 (32–82)	*.861*
Sex (M:F)	17:22	4:7	5:1	*.151*
Hypertension	9	4	1	*.604*
Diabetes	3	0	0	*.516*
Symptoms and signs				
Headache	39	9	5	*.025*
Dizziness	4	0	4	
Nausea	3	4	2	*.034*
Brainstem signs	0	0	4	
Seizure	0	2	0	
Unconsciousness	0	1	0	
Symptom onset–hospital visit				
Mean (range, d)	5.8 (0–19)	1.6 (0–7)	1.3 9 (0–4)	*.001*
Headache start–resolve				
Mean (range, d)	14 (5–52)	-	5.5 (2–13)	*.033*
Headache onset during				
ADL	35	8	6	*.207*
Sleep	3	1	0	*.773*
Stressful	15	2	3	*.632*
Headache characteristics				
Occipito-nuchal	33	5	5	*.022*
Hemicranial	31	2	4	*.000*
Ipsilateral to dissection	27	1	4	*.001*
Occur acutely	36	9	5	*.554*
Severe (VAS > 7)	28	8	2	*.165*
Imaging changes (All through the follow up period)				
Onset–First imaging change				
Mean (range, d)	141.0 (6–1193)		374.7 (51–1690)	*.419*
Onset–End of imaging change				
Mean (range, d)	194.9 (6–1193)		389.2 (51–1690)	*.494*
Normalization	18		2	*.352*
Imaging changes (Follow up period restricted to 1 yr)				
Onset–First imaging change				
Mean (range, d)	77.6 (6–196)		111.6 (51–170)	*.210*
Onset–End of imaging change				
Mean (range, d)	92.0 (6–223)		129.0 (51–175)	*.933*
Duration of imaging change				
Mean (range, d)	81.3 (0–210)		127.6 (47–172)	*.475*
Normalization	18		2	*.182*

ADL = activities of daily living, VAS = visual analog scale.

Table 2

The characteristics of the headache due to unruptured vertebral artery dissections and comparison with other previous study.

Characteristics (%)	Our study	Shibahara[12]	Matsumoto[16]
Acute pain	89.3		71
Pain on occipito-nuchal	76.8	73	92
Severe pain	67.9		
Pain in unilateral hemisphere	66.1		75
Nausea, vomiting	16.1	20	17
Dizziness or vertigo	14.0	42	

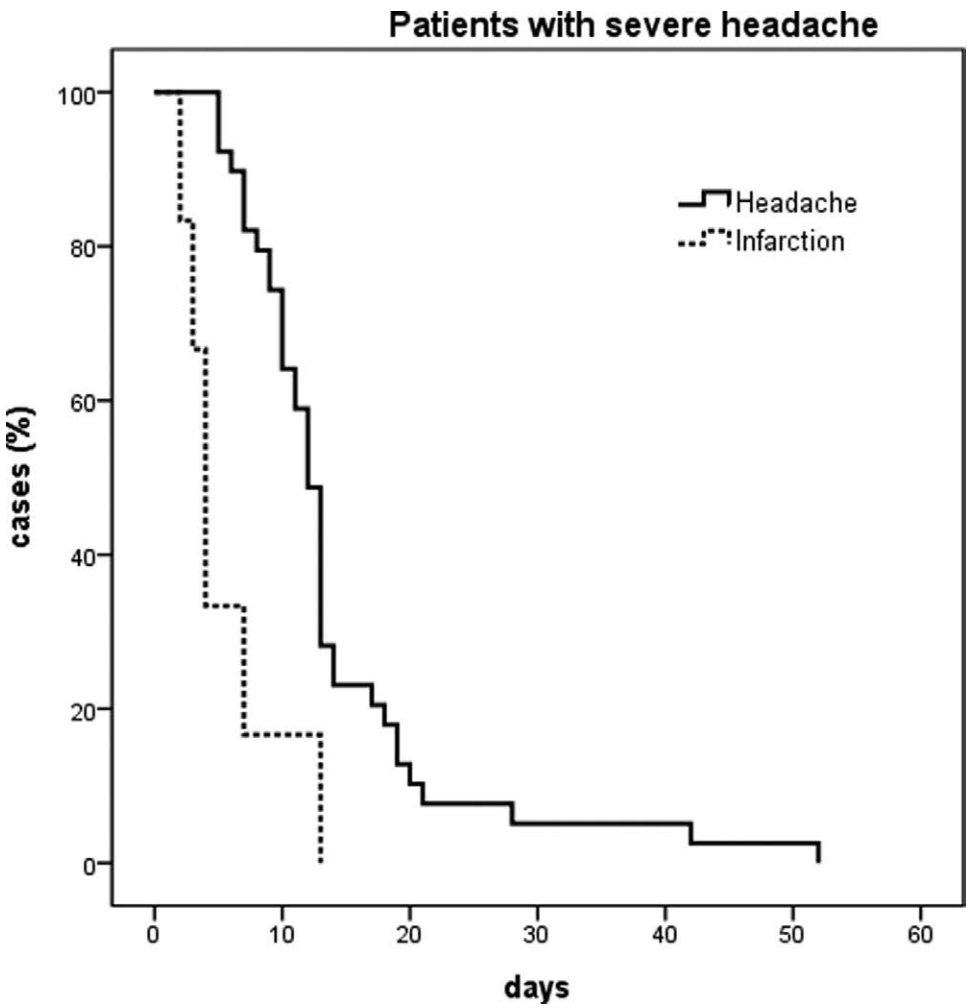

Figure 2. Kaplan–Meier analysis of the headache resolution rate. Most headaches relieved within 2 weeks in both the headache and infarction groups, and all disappeared within 8 weeks.

due to bleeding or infarction; however, its presence does not necessarily imply that such an event has occurred. Most patients in the hemorrhage and infarction groups visited the hospital earlier because they had neurological symptoms or more intense pain than those in the headache group (0–7, mean 1.6 days; 0–4, mean 1.3 days, respectively). Sometimes, in the hemorrhage group, hospital visits delayed if the pain was less intense (2, 4 and 7 days). However, in the headache group, the patient's visit was frequently delayed (0–19, mean 5.8 days, $P = .001$).

The pain was generally confined to the hemi-cranial region, and in many cases in the headache and infarction group, it was localized to the ipsilateral occipito-nuchal region (69.2% and 80%, respectively). However, in the hemorrhagic group, the pain was usually global and less localized to the side of the lesion (9%, $P < .05$). In contrast, although pain occurred acutely in all groups, the severity of pain was relatively lower in the infarct group than in the other 2 groups. Acute, severe pain originating in the occipito-nuchal or hemi-cranial region was the most typical headache in pearl and string type ICVAD. (Table 2). Most of these headaches resolved within 2 weeks and did not exceed 8 weeks (Fig. 2).

3.3. When does image change start and end?

When multiple imaging studies were performed at short intervals, image changes were not a single event. Instead, a series of events continued to improve or deteriorate over time. The first images showing normalization appeared on day 6 after

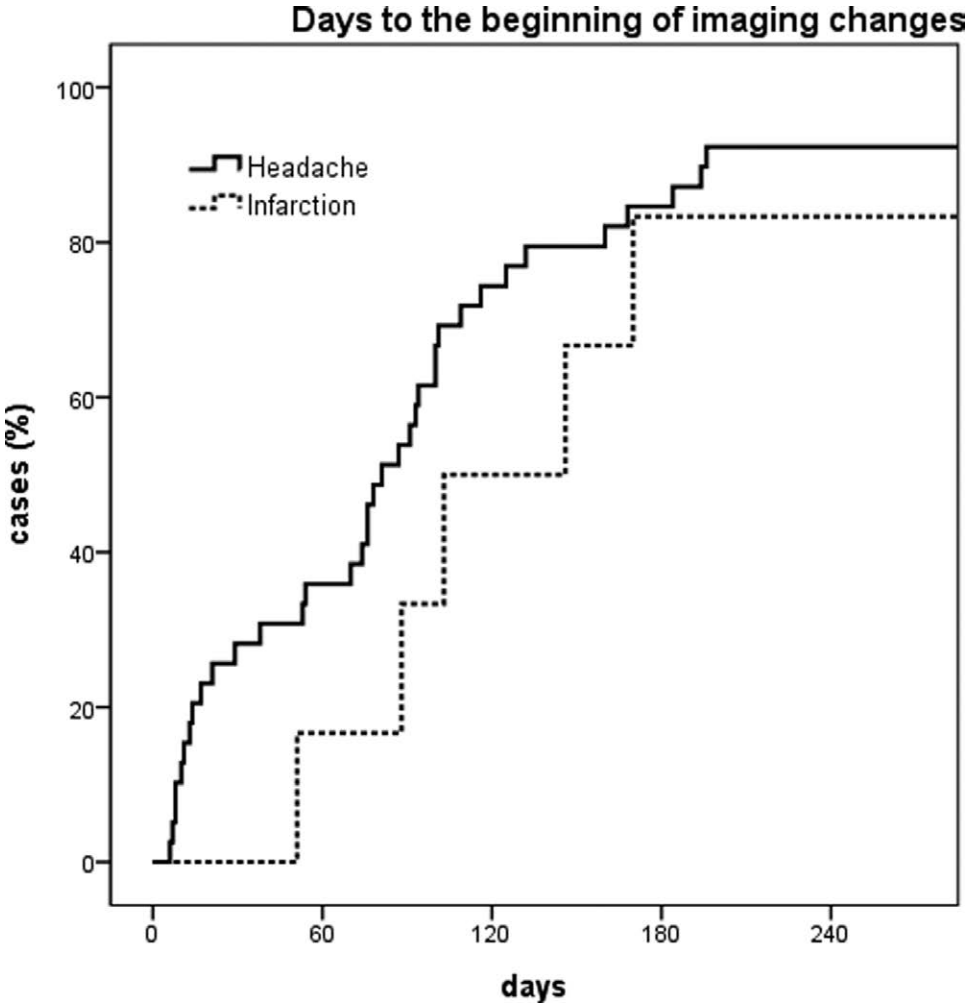

Figure 3. Kaplan–Meier curve showing the cumulative rate of detection of the first image change. The image changes occur steadily for 7 months in both headache and infarction group, after which new imaging changes rarely begin.

pain onset in the headache group, and on day 51 in the infarction group. All changes started before 3rd month and ended after 6 to 7 months when the image tracking period was limited to 1 year or less (Figs. 3 and 4). The first 2 months of the image change period overlapped with the headache resolution period (Fig. 5). However, headache resolution did not necessarily indicate ICVAD normalization. Instead, the image continued to change, even after the headache had already resolved. Regardless of improvement or deterioration, the rate of morphological change was 10.8% at 1 month, 27.0% at 3 months, and 78.4% at 6 months.

There were no age or sex differences among the 3 groups, and a history of hypertension and diabetes was not associated with the development of ICVAD. For the management of headache and dissection, analgesics, antiplatelet agents, and statins were administered over various periods. High blood pressure and blood sugar levels were also controlled. Because there are many different ways to take these drugs, their effects on early pain relief and angiographic improvement have not been analyzed.

4. Discussion

Spontaneous intracranial arterial dissection occurs more frequently in the vertebral artery and can lead to ischemic stroke or hemorrhage.[17,18] However, while extracranial and anterior circulation dissection are more common in the non-Asian population, ICVAD is more common in the Asian population. Owing to these ethnic differences in the site of dissection, the risk of ICVAD can be overlooked or overestimated by geographic or demographic characteristics.[19]

Although headaches due to ICVAD can be typical, it is difficult to determine the presence or absence of abnormalities based on the pain pattern alone, given the variety of pain tolerances and expressions of each patient.[16] In contrast, noninvasive angiographic studies, such as CTA or MRA, can easily detect vascular abnormalities, as well as hemorrhage or infarction.[20] Hemorrhage or infarction due to ICVAD usually occurs concurrently with headache or neurological symptoms, but headache may sometimes precede vascular events.[8,9] Therefore, if some of the typical features of ICVAD, such as pain on occipito-nuchal region, unilateral, severe, acute, are accompanied by initial headache, angiographic studies using CTA or MRA can easily provide early detection of ICVAD.[16,21]

4.1. Why are pearl and string signs important?

Given the variety of morphologies, it is difficult to distinguish between acute and chronic ICVADs.[22,23] Sudden onset of headache or neck pain and chronological changes in angiographic images are strong indicators of acute vertebral artery dissection.[8] As asymptomatic ICVAD rarely shows morphological changes during the follow-up period, asymptomatic dissections without image changes over time can be considered chronic.[3]

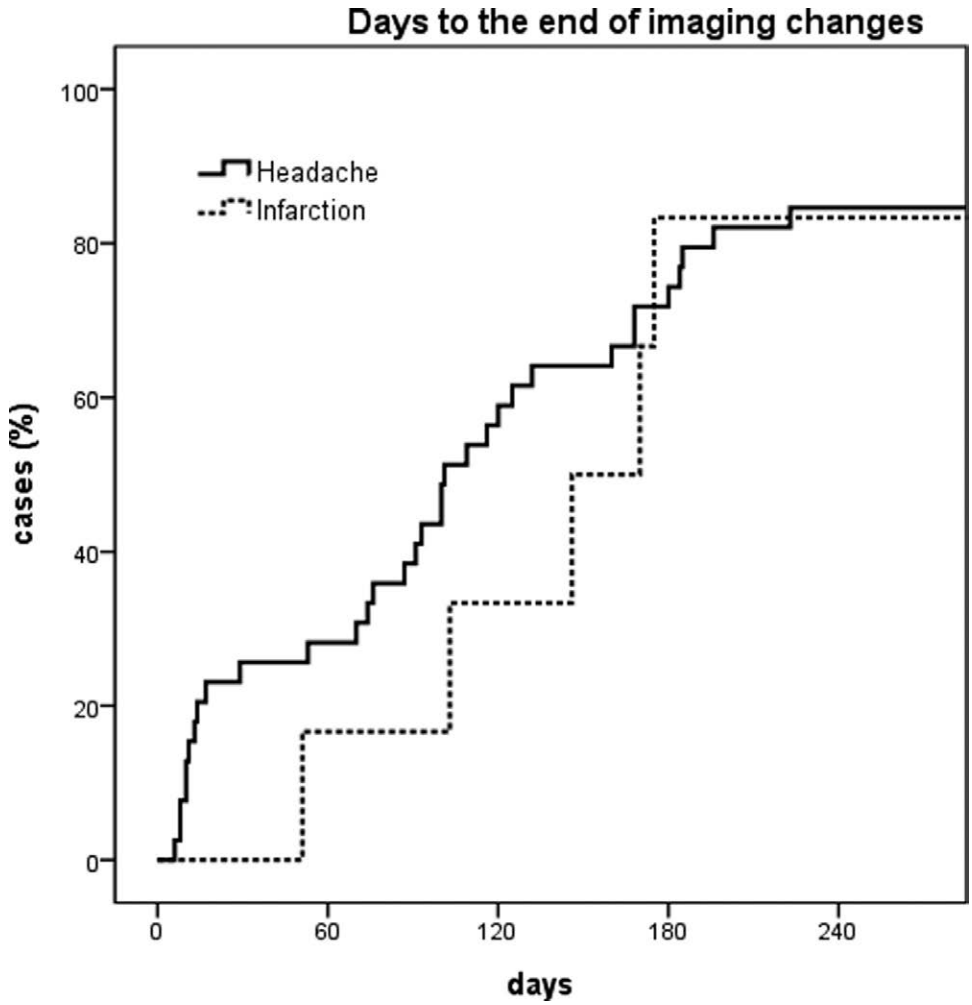

Figure 4. Kaplan–Meier curve showing cumulative rate of stabilization of image changes. Most image changes that started within a 7-month period usually end within the same period. Therefore, this period can be regarded as the period during which most pathophysiological changes occur.

ICVAD has been characterized according to radiological morphology, such as dilatation, stenosis, alternating stenosis and dilatation (pearl and string sign), and occlusion.[1,2,4–6,22,23] It is not clear why ICVADs have various morphologies, but the pearl and string signs that can be observed in both ruptured and unruptured lesions are more often seen in ruptured dissection.[12,24] In addition, delayed SAH has been reported to occur more often in ICVADs which shows the pearl and string sign.[8] Therefore, the pearl and sting sign with acute headache can be a good reason for further investigation to monitor the progression of ICVAD.

4.2. Pathophysiology of occurrence and spontaneous healing of the dissection

Dissection of a cerebral artery usually leads to flow disturbance by compromising its lumen with an intimal flap or tear by breaking the entire wall. Subsequent events result in a broad spectrum of diseases, characterized by mild symptoms, such as headache and dizziness, infarction, or devastating hemorrhage. Although mild symptomatic dissections usually heal spontaneously, some may develop into dangerous lesions within a short period of time.

The structural differences that lead to variations in the presentation of arterial dissections remain unclear. In several autopsy cases, it has been demonstrated that the location of the dissection plane determines the clinical presentation, indicating that subadventitial dissections are more likely to cause arterial wall rupture and subintimal dissection that causes intramural hematoma is more likely to result in luminal occlusion.[25] The former occurs more frequently in the vertebrobasilar system, whereas the latter occurs more frequently in the internal carotid system.[26] In other autopsy cases of vertebrobasilar artery dissection, the ruptured portions were located under the thin adventitia.[27,28]

However, the healing processes of IVADs have not yet been elucidated. Dissection specimens collected between 6 hours and 35 days after the onset of SAH showed initiation of the healing process with neointimal proliferation as well as extensive destruction of the internal elastic lamina and media. The neointima, composed mainly of newly synthesized smooth muscle cells and collagen fibers, extends forward from the disrupted ends of the media to the ruptured portion.[29] A series of MR vessel wall images also revealed reduction of hematomas and double lumen and wall enhancement over time.[30] These findings suggest that image changes may end up at various healing stages due to the complexity of the regeneration mechanism.

4.3. How long should we continue follow-up and when we decide to treat?

In our study, most headaches from acute pearl and string type ICVAD resolved within 2 weeks and did not last longer than 8 weeks. Meanwhile, the earliest signs of improvement appeared in imaging studies as early as 6 days to as late as 51 days after the onset of pain. Therefore, the first 2 months of the image change period overlapped with the headache resolution period.

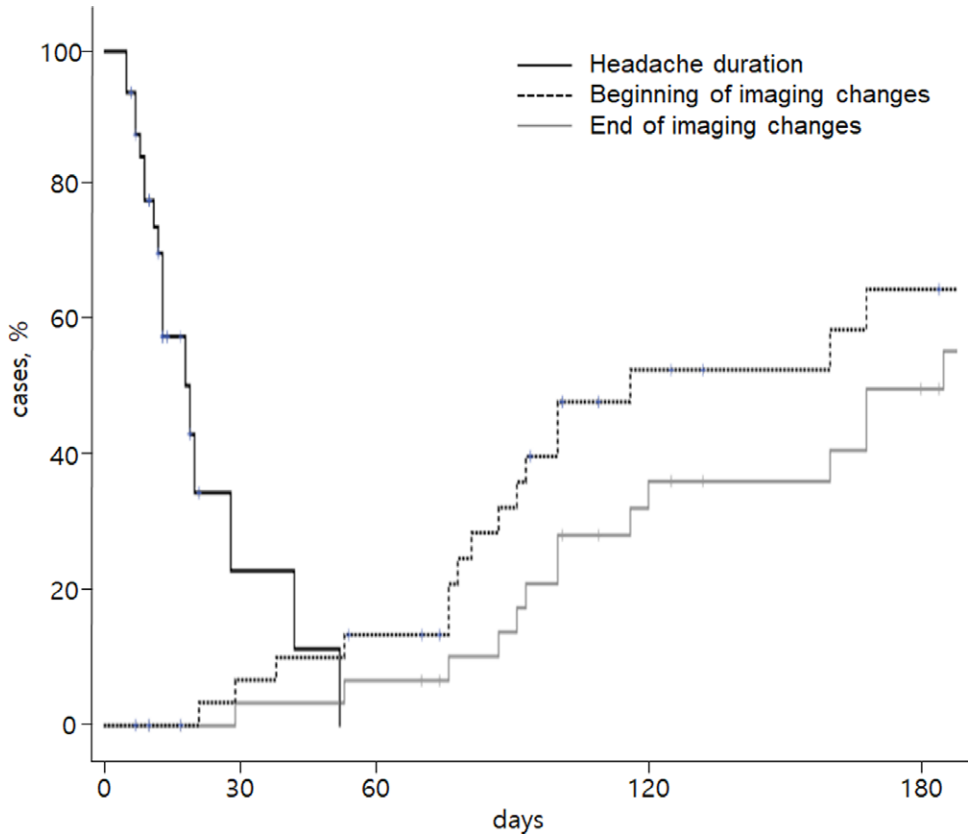

Figure 5. Relationship between the headache resolution period and the image change period. Note the 4 to 8 weeks that the 2 periods overlap. Image changes occur at the same time as the headache resolves and continue for several months after the headache has subsided.

Image changes occur at the same time as the headache resolves and continue for several months after the headache has subsided. Although many ICVADs have shown improvement on follow-up imaging, some ICVADs have worsened; therefore, headache relief does not necessarily imply normalization of ICVADs. Although it is still unclear which factors are related to ICVAD enlargement, Horio et al reported that approximately 25% of ICVADs showed enlargement within 30 days.[31]

Since the dissection is likely to worsen even after the headache disappears, the image changes continue over several months and rupture of unruptured ICVAD is unpredictable; therefore, it is desirable to conduct continuous imaging studies regularly after the initiation of dissection until stabilization is confirmed. Based on our study, we propose an early follow-up imaging study at 1 week and 1 month after the initial imaging study to determine the direction of image changes and detect early exacerbation, and then at 3- or 6-month intervals to confirm healing or stabilization. Surgical or endovascular interventions should be considered when the dissection grows or extends, forms saccular dilation, and aggravates neurological symptoms.[8,22]

5. Limitations

Although this study has many biases as a retrospective observational study, the exclusion of a few cases due to lack of follow-up data may have affected the analysis. However, this is the largest homogenous subgroup consisting only of pearl and string type ICVADs and had a long-term follow-up.

6. Conclusions

In acute ICVADs, image changes occur at the same time as the headache resolves and continue for several months after the headache has subsided. It starts as early as a week and usually lasts several months. Most image changes occur within 7 months, but sometimes can last a year or more. Since the dissection is likely to worsen even after the headache disappears, the image changes continue over several months, and prediction of rupture of unruptured ICVAD is unpredictable, it is desirable to conduct continuous imaging studies regularly from the initiation of dissection until stabilization is confirmed.

Author contributions

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