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Atlantoaxial Subluxation in Different Intraoperative Head Positions in Patients with Rheumatoid Arthritis

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Background: **Disorders of the cervical spine are often observed in patients with rheumatoid arthritis (RA). However, the best head position for RA patients with atlantoaxial subluxation in the perioperative period is unknown. This study investigated head position during general anesthesia for the patients with RA and proven atlantoaxial subluxation.**

Methods: **During anesthesia of patients with RA and proven atlantoaxial subluxation, the authors used fluoroscopy to obtain a lateral view of the upper cervical spine in four different positions: the mask position, the intubation position, the flat pillow position, and the protrusion position. Copies of the still fluoroscopic images were used to determine the anterior atlantodental interval, the posterior atlantodental interval, and the angle of atlas and axis (C1–C2 angle).**

Results: **The anterior atlantodental interval was significantly smaller in the protrusion position (2.3 mm) than in the flat pillow position (5.1 mm) ($P < 0.05$). The posterior atlantodental interval was significantly greater in the protrusion position (18.9 mm) than in the flat pillow position (16.2 mm) ($P < 0.05$). The C1–C2 angle was, on average, 9.3° greater in the protrusion position than in the flat pillow position ($P < 0.05$).**

Conclusion: **This study showed that the protrusion position using a flat pillow and a donut-shaped pillow during general anesthesia reduced the anterior atlantodental interval and increased the posterior atlantodental interval in RA patients with atlantoaxial subluxation. This suggests that the protrusion position, which involves support of the upper cervical spine and extension at the craniocervical junction, might be advantageous for these patients.**

DISORDERS of the cervical spine that occur as complications of rheumatoid arthritis (RA) include (1) atlantoaxial subluxation (AAS, anterior or rarely posterior); (2) vertical subluxation (erosion of the lateral masses of C2 allowing translocation of the dens, due to settling of the atlas and cranium); and (3) subaxial subluxation, which results in vertebral instability below C3 and ladder-step spine. Among these, anterior AAS is the most common and accounts for approximately two thirds of cervical spinal disorders in patients with RA.[1–4]

AAS is frequently associated with spinal cord compression and the consequent neurologic deficits.[5–7] In addition, mortality in RA patients with AAS is greater than expected.[8–11] Riise *et al.*[9] reported that among 241 patients with RA, patients with AAS had an eightfold greater mortality than those without AAS. Postmortem analyses of sudden death in patients with RA and AAS are revealing.[11–13] For example, compression within the C1–C2 area was the cause of death in a patient with RA after wrist arthrodesis.[11] In addition, a patient with RA who underwent abdominal surgery for ileus developed tetraplegia due to dislocation of the dental process during intensive care.[13] Mikulowski *et al.*[12] investigated 11 autopsy cases of severe AAS and found that sudden death was not necessarily preceded by neurologic symptoms. Therefore, absence of preoperative neurologic symptoms does not assure perioperative safety. And, of course, when subluxation occurs during general anesthesia, neurologic symptoms will not be apparent.

AAS–associated spinal cord compression should be avoided; specific precautions are thus prudent in patients with RA who require general anesthesia. Anesthetists should position patients in a fashion that prevents compression of spinal cord, especially during orotracheal intubation.[14]

In patients with AAS, subluxation is exacerbated by cervical flexion and reduced by cervical extension. Weissman *et al.*[15] reported that AAS-associated spinal cord compression occurs when subluxation is 9 mm or more in the anterior atlantodental interval. Avoiding excessive flexion of the cervical spine during orotracheal intubation, for example, presumably reduces risk in patients with AAS. However, the best position of the head during anesthetic induction and surgery for these patients remains unknown. Therefore, we tested the hypothesis that keeping the patient's head and neck protruded with a combination of a flat pillow and a donut-shaped pillow reduces AAS compared with using a flat pillow alone.

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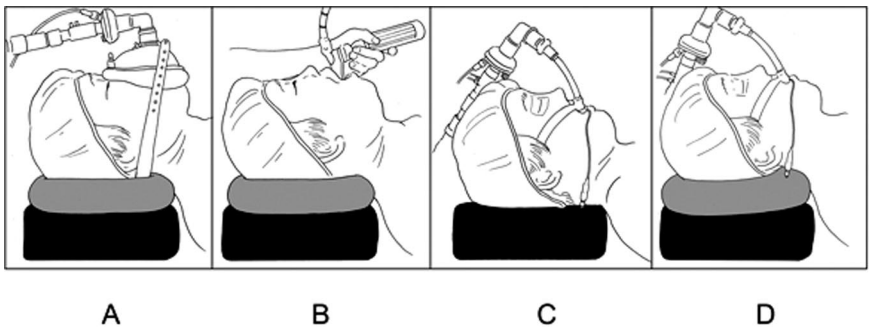

Fig. 1. Positions of head and neck during measurements. (*A*) During airway management (mask position); (*B*) during orotracheal intubation (intubation position); (*C*) after orotracheal intubation with the head positioned on a flat pillow (flat pillow position); (*D*) after orotracheal intubation with the head positioned on a donut-shaped pillow on top of the flat pillow (protrusion position).

Materials and Methods

After obtaining local research ethics committee approval (Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan) and written informed consent, we enrolled 10 patients with RA who demonstrated radiographic evidence of at least 5 mm of AAS. All were scheduled to undergo general anesthesia for orthopedic procedures. None had preoperative neurologic symptoms, such as sensory disturbance or paresthesia in the arms or legs.

Before the Day of Surgery

Conventional lateral cervical radiographs were obtained before the day of surgery with the patient's head in three positions (flexion, neutral, and extension), with the patient sitting or standing.

During Induction of Anesthesia

One anesthesiologist performed anesthesia for all patients. Thirty minutes before induction of anesthesia, patients were given 0.5 mg atropine sulfate and 50 mg hydroxyzine hydrochloride intramuscularly. Anesthesia was induced by intravenous administration of 2 mg/kg propofol and 0.15 mg/kg vecuronium bromide. During induction of anesthesia, a lateral radiographic view of the upper cervical spine was obtain in two positions: (1) during airway control with a facemask (mask position; fig. 1A), and (2) during orotracheal intubation at the actual point of maximal laryngeal exposure with a conventional Macintosh laryngoscope (intubation position; fig. 1B) with the head positioned on a flat pillow (5.5 cm thick) set on the surgical table combined with a donut-shaped pillow (3.5 cm thick, 17.5 cm in diameter, inside diameter 8 cm). Tracheal intubation was performed without difficulty in all patients.

After Induction of General Anesthesia

The trachea was intubated with a reinforced tube with a Murphy eye, and radiographs were performed with two different head positions: (1) head positioned on a flat pillow alone (flat pillow position; fig. 1C) and (2) head positioned on a flat pillow combined with a donut-shaped pillow (protrusion position; fig. 1D). By using the donut-shaped pillow, the cervical spine was supported with the edge of the donut, keeping craniocervical extension. After taking hard copies of positions (3) and (4), the position that showed less AAS was chosen for the position during surgery. Distances of the head elevated from the operation table were approximately 6 cm in the mask, intubation, and protrusion positions and 4 cm in the flat pillow position.

Anesthesia was maintained with 0.4–1.0% sevoflurane and 66% nitrous oxide in oxygen. After an initial dose of 3 μg/kg fentanyl, continuous infusion of fentanyl at a rate of 2 $\mu g \cdot kg^{-1} \cdot h^{-1}$ was performed for the first 3 h of surgery. An intravenous infusion of vecuronium, initially set to 0.025 $mg \cdot kg^{-1} \cdot h^{-1}$, was adjusted to maintain one or two twitches in response to supermaximal stimulation of the ulnar nerve at the wrist. Mechanical ventilation was adjusted to maintain end-tidal partial pressure of carbon dioxide between 35 and 40 mmHg.

Copies of the still fluoroscopic images were used to determine anterior atlantodental interval (ADI), posterior atlantodental interval (PADI), and angle of atlas and axis (C1–C2 angle; angle between a line parallel to the distal line of C1 and C2)[16,17] (fig. 2).

Digital x-ray photographs and scanned copies of the fluoroscopic images were captured by an FTI-1000 Imaging System (FUJI Photo Film Co. Ltd., Tokyo, Japan). The images were digitally scanned for the measurements of distances and angles. Freeware "image j^R" was used for the data calibration. To calibrate the length of measurements, we used the inner diameter of the atlas measured on the x-ray photographs that showed a lateral view of the cervical spine. All measurements were performed on digitally magnified images by an investigator blinded to head position.

Statistical Analysis

A repeated-measures analysis of variance with Tukey tests was used for statistical analysis in comparing ADI, PADI, and C1–C2 angle in different positions before surgery and during general anesthesia. Data are presented as mean ± SD or mean (range); $P < 0.05$ was considered statistically significant.

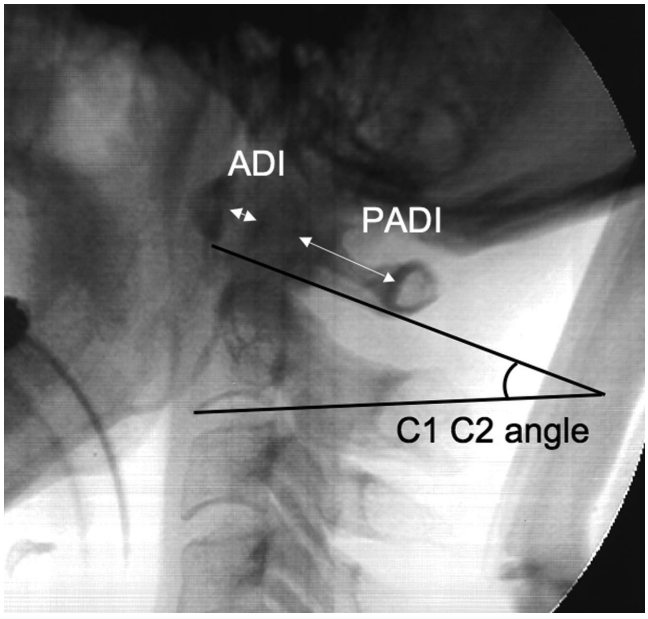

Fig. 2. Measurements on lateral cervical radiographs. ADI = anterior atlantodental intervals; C1–C2 angle = angle between distal line of C1 and C2; PADI = posterior atlantodental interval.

Results

In 2 of the 10 consenting patients, the mask position was not recorded. Therefore, the data from these patients were excluded from the data analyses. The remaining patients were female. They were, on average, 58 yr old (range, 43–67 yr) with an 18-yr history of RA (4–29 yr). Preoperative ADI during neck flexion averaged 7.4 mm (range, 6.0–10.2 mm). None of the patients developed neurologic symptoms during their lateral cervical radiographs with the head in flexion, neutral position, or extension.

ADI averaged 3.4 (1.3–8.3) mm in the mask position and 3.5 (0.9–7.1) mm in the intubation position. Changes of ADI between the mask and intubation positions were not consistent and ranged from −1.2 to 2.4 mm. However, none of the patients showed any further AAS in the intubation position than they experienced in the preoperative cervical flexion position. During surgery, ADI averaged 5.1 (3.9–6.7) mm in the flat pillow position and 2.3 (1.0–3.8) mm in protrusion position; it was significantly greater in the flat pillow position than in the protrusion position ($P < 0.05$; fig. 3). PADI averaged 19.6 (16.6–24.8) mm in the mask position, 18.9 (14.7–23.9) mm in the intubation position, 16.2 (12.8–19.7) mm in the flat pillow position, and 18.9 (15.2–22.6) mm in the protrusion position. PADI was significantly smaller in the flat pillow position than in the protrusion position ($P < 0.05$; fig. 4). The C1–C2 angle was, on average, 9.3° greater in the protrusion position than in the flat pillow position ($P < 0.05$; fig. 5). None of the patients had neurologic complications after surgery.

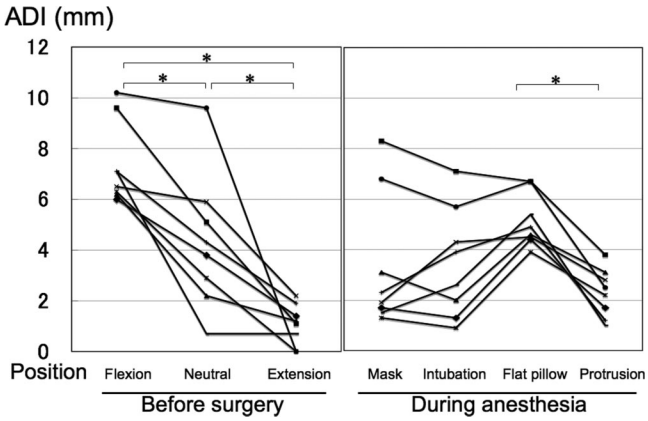

Fig. 3. Anterior atlantodental intervals (ADI) in millimeters measured preoperatively and during general anesthesia. Mask position: during airway management. Intubation position: during orotracheal intubation. Flat pillow position: after orotracheal intubation with the head positioned on a flat pillow. Protrusion position: after orotracheal intubation with the head positioned on a donut-shaped pillow on top of the flat pillow. * $P < 0.05$.

Discussion

In eight patients with RA and proven AAS, we were able to perform orotracheal intubation without causing further subluxation of the atlantoaxial joint than observed in the preoperative cervical flexion position. ADI averaged 2.8 mm less when the patients were positioned on a flat pillow combined with a donut-shaped pillow than when they were positioned on a flat pillow alone. The amount of AAS was thus reduced when the head was supported by both types of pillows.

A dynamic analysis of AAS, performed primarily in unanesthetized patients, showed that subluxation is exacerbated by cervical flexion and reduced by cervical extension.[16] Hino *et al.*[18] analyzed the dynamics of the

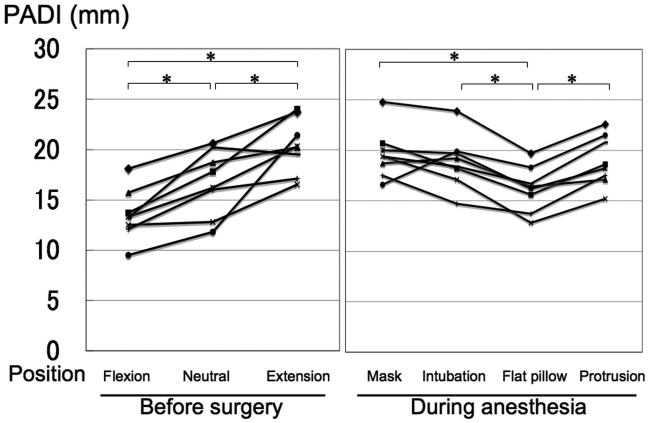

Fig. 4. Posterior atlantodental interval (PADI) in millimeters measured preoperatively and during general anesthesia. Mask position: during airway management. Intubation position: during orotracheal intubation. Flat pillow position: after orotracheal intubation with the head positioned on a flat pillow. Protrusion position: after orotracheal intubation with the head positioned on a donut-shaped pillow on top of the flat pillow. * $P < 0.05$.

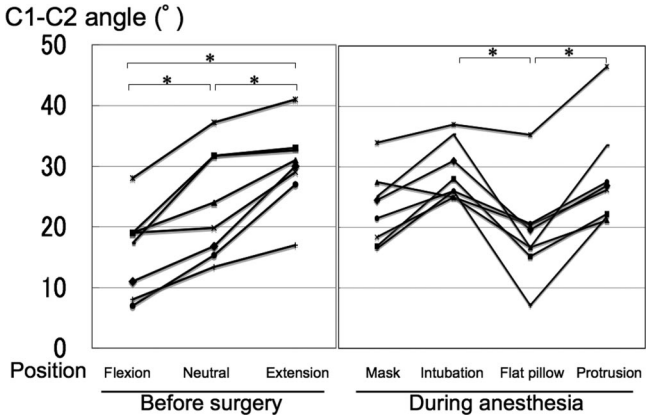

Fig. 5. Angle between distal line of C1 and C2 (C1–C2 angle) measured preoperatively and during general anesthesia. Mask position: during airway management. Intubation position: during orotracheal intubation. Flat pillow position: after orotracheal intubation with the head positioned on a flat pillow. Protrusion position: after orotracheal intubation with the head positioned on a donut-shaped pillow on top of the flat pillow. * $P < 0.05$.

unstable cervical spine using cineradiography and found different motion patterns between normal and pathologic cervical spines. Kinematics of the cervical spine, not only during flexion–extension but also with different cervical motions, have also been reported. For example, Ordway *et al.*[19] performed lateral radiographic analysis of the cervical spine in 20 asymptomatic volunteers to quantify the contribution of each cervical segment to each of the cervical end-range positions: flexion, extension, protrusion, and retraction. These studies revealed that motions besides flexion–extension affected segmental cervical kinetics. In their radiographic analysis of the upper cervical spine in 24 awake patients with RA and C1–C2 instability, Maeda *et al.*[20] reported that retraction produced both maximal C1–C2 flexion and anterior C1–C2 subluxation and that protrusion produced maximal C1–C2 extension. However, in some patients with severe C1–C2 instability, protrusion also resulted in C1–C2 subluxation, even though the C1–C2 was maximally extended.[20]

Few reports have been published about patients with AAS in the perioperative period. Horton *et al.*[21] reported in their study of lateral x-ray during direct laryngoscopy in a standard intubating position that the lower neck was relatively straight and increasing curvature occurred from the mid cervical spine upward. Extension at the atlantoaxial joint was probably near maximum. Sawin *et al.*[22] studied segmental cervical motion produced by direct laryngoscopy and orotracheal intubation in human subjects without cervical abnormality. They found that majority of cervical motion is produced at the occipitoatlantal and atlantoaxial joints. The subaxial cervical segments (C2–C5) are displaced only minimally.

Takenaka *et al.*[23] describe a patient with RA and severe AAS in the "sniffing position." They performed radiologic examination of the cervical spine for awake RA patients the day before surgery. Radiographs revealed marked AAS of the ADI of 10 mm in the sniffing position (obtained by placing a 7-cm pillow under the head), compared with an ADI of 2 mm in the extension of the entire cervical spine accomplished by bending part of the table. They proposed that when the neck was flexed by placing a pillow under the occiput for achieving the sniffing position, the occiput–atlas component was pushed forward, leaving the axis–lower component behind, resulting in AAS. They noted that whether AAS is corrected might depend on the degree to which ligaments stabilizing the occipitoatlantoaxial complex are disrupted.

The sniffing position used in anesthesiology appears similar to the posture Ordway *et al.*[19] described as the cervical spine protrusion position, defined as maximal forward gliding or anterior translation of the head while zero sagittal rotation is maintained. The definition of the sniffing position is unclear, and it is sometimes misinterpreted as raising the patient's head by gliding it forward. However, putting the patient's head on only a flat pillow may result in the cervical flexion position, which is not desired for AAS. Our strategy to avoid further AAS was to use a low pillow to avoid cervical flexion and add a donut-shaped pillow to keep the patient's head extended to maintain the protrusion position. Adding the donut-shaped pillow to the flat pillow pushes the head anterior to the trunk, causing relative anteflexion of the lower cervical spine. Raising a patient's jaw brings the upper cervical spine, mainly C1–C2, to a relatively extended position. Concomitant use of a donut-shaped pillow increased the C1–C2 angle to a relatively extended position by 9° more than that using the flat pillow alone. This position of the cervical spine is consistent with the protrusion position as "maximal forward gliding or anterior translation of the head while zero sagittal rotation is maintained."[17] By using a donut-shaped pillow in combination with a flat pillow, the upper cervical spine, mainly C2 and C3, was supported by the caudal portion of the donut-shaped pillow. Then, the upper cervical spine was pushed up, and simultaneously, the patient's head extended downward over the fulcrum of the donut-shaped pillow; craniocervical junction extension was achieved, and AAS was thus reduced. By contrast, when the flat pillow alone was used, the upper cervical spine was supported less so that the upper cervical spine was not displaced forward; meanwhile, the patient's head was not permitted to fall back. This position is similar to that reported by Takenaka *et al.*[23]

A limitation of our study was that most of the patients participating in this study had mild to moderate AAS. Our conclusions may thus not apply to patients with severe subluxation, patients with vertical subluxation, or patients with preexisting neurologic symptoms. When patients demonstrate severe AAS before surgery, it may

be prudent to use fluoroscopy to guide the head positioning and intubation, under preparation for the use of a cervical collar and an awake intubation.

In summary, this study showed that protrusion position using a flat pillow and a donut-shaped pillow during general anesthesia reduced ADI and increased PADI in eight RA patients with AAS. This suggests that the protrusion position might be a desirable position for these patients.

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