Radiology

Axillary Lymphadenopathy after Pfizer-BioNTech and Moderna COVID-19 Vaccination: MRI Evaluation

Manuscript Type: Original research

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The Department of Computational Diagnostic Radiology and Preventive Medicine is sponsored by HIMEDIC, Inc, and Siemens Japan KK.

An earlier incorrect version of this article appeared online. This article was corrected on September 14, 2022.

Data sharing statement

Data generated or analyzed during the study are available from the corresponding author by request provided that the institutional review board of the authors' institution permits it.

Summary statement

In individuals with mRNA COVID-19 vaccination, 1% had enlarged axillary nodes larger than or equal to 10 mm in size at MRI; all enlarged nodes had normal apparent diffusion coefficients.

Key Results

1. We evaluated 433 participants with their second dose of mRNA vaccine and chest MRI. Vaccination-related axillary lymphadenopathy 1-14 days after vaccination was present in 65%.
2. Younger age, female sex, and Moderna vaccine were predisposing factors for vaccination-related axillary lymphadenopathy ($p < .001$, $p = .005$, and $p = .003$, respectively).
3. Enlarged lymph nodes demonstrated a higher signal intensity on T2-weighted images, while the apparent diffusion coefficient remained within the normal range.

Abbreviations

T2WI: T2-weighted image

ADC: apparent diffusion coefficient

DWI: diffusion-weighted image

Abstract

Background

COVID-19 vaccination-related axillary lymphadenopathy has become an important problem in cancer imaging. Data is needed to update or support imaging guidelines for conducting appropriate follow-up.

Purpose

To investigate the prevalence, predisposing factors, and MRI characteristics of COVID-19 vaccination-related axillary lymphadenopathy.

Materials and Methods

Prospectively collected pre-vaccination and post-vaccination chest MRI scans were secondarily analyzed. Participants who underwent two doses of Pfizer-BioNtech or Moderna COVID-19 vaccine and chest MRI from June to October 2021 were included. Enlarged axillary lymph nodes were identified on post-vaccination MRI comparing with pre-vaccination MRI. Lymph node diameters, signal intensity on T2-weighted images (T2WIs) and apparent diffusion coefficient (ADC) of the largest enlarged lymph node were measured. These values were compared between pre-vaccination and post-vaccination MRI with the Wilcoxon signed-rank test.

Results

We evaluated 433 participants (mean age ± standard deviation, 65 years ± 11 years), 300 males and 133 females. The prevalence of axillary lymphadenopathy in participants 1-14 days

after vaccination was 65% (30/46). Participants with lymphadenopathy were younger than those without lymphadenopathy ($p < 0.001$). Female sex and Moderna vaccine were predisposing factors ($p = 0.005$ and $p = 0.003$, respectively). Five or more enlarged lymph nodes were noted in 2% (8/433). Enlarged lymph nodes ≥ 10 mm in the short axis were noted in 1% (4/433). The median signal intensity relative to the muscle on T2WI was 4.0. Enlarged lymph nodes demonstrated a higher signal intensity on T2WI ($p = 0.002$). The median ADC of enlarged lymph nodes post vaccination was 1.1 x 10^{-3} mm^2/sec with the range 0.6 – 2.0 x 10^{-3} mm^2/sec in 90 participants, and thus ADC remained normal.

Conclusions

Axillary lymphadenopathy after the second dose of Pfizer-BioNtech or Moderna COVID-19 vaccination was frequent within two weeks after vaccination, was typically less than 10mm in size, and had normal ADC.

Introduction

With the mass COVID-19 vaccination rollout worldwide, vaccination-related lymphadenopathy has become an important problem for patients, clinicians, and cancer researchers. Vaccination-related lymphadenopathy is a frequent imaging finding typically observed in the axilla ipsilateral to the vaccinated site after administration of COVID-19 vaccines, and it can present as a diagnostic dilemma in cancer imaging. It can lead to underdiagnosis or overdiagnosis and undertreatment or overtreatment, as well as heightened anxiety (1, 2).

The Society of Breast Imaging, RSNA, and other authors proposed recommendations addressing vaccination-related lymphadenopathy seen on images (2-6). RSNA recommended that imaging should be scheduled before the first vaccination dose, or at least 6 weeks after the final vaccination dose whenever possible (2). The Society of Breast Imaging recommended to consider a follow-up examination in 4-12 weeks for unilateral axillary lymphadenopathy in women vaccinated in the past 4 weeks (3). On the other hand, Wolfson et al. have recently insisted that screening mammography should not be delayed after COVID-19 vaccination (6).

Recommendations in the early days of 2021 are provisional, and more appropriate management strategies for vaccination-related lymphadenopathy are needed in both the general population and high-risk oncology patients (1). RSNA recommended reporting morphologic, functional, and metabolic features of lymphadenopathy encountered at imaging following vaccination (2), and it is necessary to establish criteria for interpreting these features. Scientific investigation on vaccination-related lymphadenopathy is paramount to revise guidelines for conducting proper follow-up and final assessment of lymphadenopathy and avoiding unnecessary imaging and invasive procedures.

To date, large cohort studies relevant to imaging of COVID-19 vaccination-related axillary

lymphadenopathy have been broadly divided into two categories. The first category comprises studies on patients with malignancies including males and females, in which lymphadenopathy is observed during staging and monitoring mainly assessed with PET/CT (7-12). The second category consists of studies on breast cancer screening with mammography and ultrasound (6, 13, 14). A recent publication using breast MRI is also in this category (15). Subjects in the second category were usually women.

The aim of this study was to investigate the prevalence, predisposing factors, and MRI characteristics of COVID-19 vaccination-related axillary lymphadenopathy in a general population, including males and females.

Materials and Methods

Study population

Institutional review board approval was obtained for this study. Our institution conducts a comprehensive health screening program including whole-body MRI. This program is an option for access to the healthcare support service offered by HIMEDIC, Inc. (Tokyo, Japan), which was established in 1994 with the aim of offering preventive medicine. The examinees were members, members' families, and members' acquaintances, who come for check-ups annually for continuous health monitoring and medical support. Before participating in the program, examinees were informed that their clinical, laboratory, and imaging data would be stored in a database and used for research purposes. Written informed consent was obtained from all participants. The questionnaire included COVID-19 vaccination information. A cohort of 1,078 consecutive participants who participated in the comprehensive health screening program including MRI from June to October 2021 was considered for inclusion in this study (Figure 1).

Among them, 630 participants had received two doses of COVID-19 vaccines (Pfizer-BioNtech or Moderna). Those who lacked vaccination information, were vaccinated in both arms, and did not undergo pre-vaccination MRI were excluded. Those with a past or current medical history of diseases that may cause axillary lymphadenopathy were excluded. Those with a past history of COVID-19 were also excluded. Consequently, 433 participants constituted the study group (Table).

Chest MRI

In this study, we selected the chest region of whole-body axial T2-weighted image (T2WI) and diffusion-weighted image (DWI) in the imaging data set of the participants. MRI was performed in the supine position using one of two 3-T MRI systems (Biograph mMR, Siemens, Munich, Germany). Fast spin-echo T2WI without fat suppression (repetition time, 1200 msec; echo time, 120 msec; turbo factor, 250; field of view, 400 mm; matrix size, 400 x 384; slice thickness, 4 mm) and echo-planar DWI (repetition time, 7840 msec; echo time, 54 msec; field of view, 450 mm; matrix size, 128 x 90; slice thickness, 4 mm; b value, 800 and 0 sec/mm^2) were obtained without a breath-hold.

Image analysis

In this study, axillary lymphadenopathy was defined as the presence of at least one enlarged axillary lymph node, and an enlarged lymph node was defined as one on post-vaccination MRI scans that was larger than the corresponding lymph node on pre-vaccination MRI scans and had a short-axis diameter ≥ 5 mm. The enlargement of lymph nodes was visually assessed, and, when noted, the short-axis and long-axis diameters were measured. The number of enlarged lymph nodes was counted. The largest enlarged lymph node was identified on post-vaccination MRI

scans, and the lymph node corresponding to the largest enlarged lymph node was identified on pre-vaccination MRI scans. The short-axis and long-axis diameters of the corresponding lymph node were also measured on pre-vaccination MRI scans.

Post-vaccination chest MRI scans were independently reviewed by two board-certificated radiologists (T. Y. and S. M., with 19 and 12 years of experience in chest MRI, respectively) for the evaluation of axillary lymphadenopathy ipsilateral to the vaccinated site, based on side-by-side comparison with pre-vaccination MRI scans. Disagreement was solved by consensus. All cases of lymphadenopathy observed in this study were considered to be induced by COVID-19 vaccination, because participants with a past or current medical history of diseases that may cause axillary lymphadenopathy were excluded from this study.

The relative signal intensity on T2-weighted images was obtained in the largest enlarged lymph node, referring a previous publication (16). To measure the signal intensity of the largest enlarged lymph node, a circular region of interest was placed on T2-weighted images from post-vaccination MRI. A region of interest was also placed on the ipsilateral pectoralis minor muscle as the reference. The relative signal intensity on T2-weighted images was calculated by dividing the signal intensity of the lymph node by the signal intensity of the pectoralis minor muscle.

To measure the apparent diffusion coefficient (ADC) of the largest enlarged lymph node, regions of interest were placed on DWI images obtained with b values of 800 and 0 sec/mm^2 at post-vaccination MRI, and ADC was calculated. When the corresponding lymph node on pre-vaccination MRI had a short-axis diameter ≥ 5 mm, the relative signal intensity on T2WI and ADC were obtained similarly. The change in ADC was calculated as post-vaccination ADC – pre-vaccination ADC.

Statistical Analysis

Continuous variables are presented as means ± standard deviation for normally distributed data and medians and [25th – 75th centiles] for nonnormally distributed data as appropriate. Inter-reader agreement was evaluated with Cohen's κ statistics. For continuous variables, the Wilcoxon rank sum test was used to compare the medians of two groups (Table). For categorical variables, the Fisher's exact test was used to compare two groups (Table). For paired continuous variables, the Wilcoxon signed-rank test was used to compare two related data (Figures 4C and 4D). Excel and statistics software (JMP Pro 16.0.0, SAS Institute, North Carolina, USA) were used to conduct analyses. $P < 0.05$ was indicative of a statistically significant difference.

Results

A total of 433 participants, including 300 males and 133 females (mean age, 65 years ± 10 years) were evaluated. The background characteristics of the participants are demonstrated in Table. Inter-reader agreement for presence or absence of lymphadenopathy was substantial (κ = 0.63).

Overall, COVID-19 vaccination-related axillary lymphadenopathy was observed in 90 of the 433 participants (21%) in this study. Participants with lymphadenopathy were significantly younger than those without lymphadenopathy (61 years ± 10 years versus 66 years ± 10 years, respectively; $p < 0.001$). Lymphadenopathy was significantly more common in females than in males (39 of 133 (29%) versus 51 of 300 (17%); $p = 0.005$). Lymphadenopathy was more common in those who received the Moderna vaccine than in those who received the Pfizer-BioNtech vaccine (17 of 43 (40%) versus 73 of 390 (19%); $p = 0.003$). Participants with lymphadenopathy underwent post-vaccination MRI significantly earlier after vaccination than participants without lymphadenopathy (median, 24 [25th – 75th centile, 12-42] days versus 67 [25th – 75th centile, 42-

96] days, $p < 0.001$).

Figure 2 demonstrates the number of participants with and without COVID-19 vaccination-related axillary lymphadenopathy according to the days after the second vaccination. The prevalence of lymphadenopathy in participants at 1-14, 15-28, 29-42, and 43-56 days after vaccination was 65% (30/46), 40% (22/55), 29% (16/55), and 18% (11/62), respectively. The prevalence of lymphadenopathy was lower than 10% more than 56 days after vaccination. Participants demonstrated lymphadenopathy as late as 109 days after vaccination in this cohort.

Figure 3A demonstrates the scatter plot of the number of enlarged lymph nodes versus the days after vaccination. Participants shortly after vaccination tended to have more enlarged lymph nodes. The median number of enlarged lymph nodes was two [25^{th} – 75^{th} centile, 1-2]. Five or more enlarged lymph nodes were noted in eight of the 433 participants (2%), and those in six of the eight participants were noted 1-14 days after vaccination.

Figure 3B demonstrates the scatter plot of the short-axis diameter of the largest enlarged lymph node versus the days after vaccination, and Figure 3C demonstrates that of the long-axis diameter. Participants shortly after vaccination tended to have larger enlarged lymph nodes. The median short-axis diameter of the largest enlarged lymph node was 6 mm [25^{th} – 75^{th} centile, 6-8 mm], and the median long-axis diameter was 9 mm [25^{th} – 75^{th} centile, 8-11 mm]. Only four of the 433 participants (1%) had enlarged lymph nodes ≥ 10 mm in the short axis.

Figure 4A demonstrates the scatter plot of the relative signal intensity on T2-weighted images of the largest enlarged lymph node versus the days after vaccination, and Figure 4B demonstrates that of ADC. Although the relative signal intensity seemed to be low in later days after vaccination, it had little connection to the days after vaccination. ADC had no relevance to the days after vaccination. The median relative signal intensity on T2-weighted images of the largest enlarged lymph node was 4.0 [25^{th} – 75^{th} centile, 3.5-5.6], and the median ADC was 1.1 x 10^{-3} mm^2/sec

[25^{th} – 75^{th} centile, 0.9-1.4 x 10^{-3} mm^2/sec].

Eleven of the 90 participants with axillary lymphadenopathy had the corresponding lymph node with a short-axis diameter ≥ 5 mm on pre-vaccination MRI scans. Figure 4C demonstrates the changes in the relative signal intensity on T2-weighted images of the largest enlarged lymph node between pre-vaccination and post-vaccination MRI, and Figure 4D demonstrates the changes in ADC. The largest enlarged lymph node on T2-weighted images of post-vaccination MRI demonstrated a higher relative signal intensity than the corresponding lymph node on T2-weighted images of pre-vaccination MRI ($p = 0.002$). The median change in ADC was -0.2 x 10^{-3} mm^2/sec [25^{th} – 75^{th} centile, -0.3 - 0 x 10^{-3} mm^2/sec]. The changes in ADC before and after vaccination was not different ($p = 0.17$). Representative MRI examples are presented in Figures 5 and 6.

Discussion

We evaluated 433 participants (mean age ± standard deviation, 65 ± 11 years), 300 males and 133 females. The prevalence of axillary lymphadenopathy in participants 1-14 days after vaccination was 65% (30/46). Participants with lymphadenopathy were significantly younger than those without lymphadenopathy (61 years ± 10 years versus 66 years ± 10 years, respectively; $p < 0.001$). Lymphadenopathy was significantly more common in females than in males (39 of 133 (29%) versus 51 of 300 (17%); $p = 0.005$). Lymphadenopathy was more common in those who received the Moderna vaccine than in those who received the Pfizer-BioNtech vaccine (17 of 43 (40%) versus 73 of 390 (19%); $p = 0.003$). Five or more enlarged lymph nodes were noted in 2% (8/433). Enlarged lymph nodes ≥ 10 mm in the short axis were noted in 1% (4/433). The median relative signal intensity on T2-weighted images of the largest

enlarged lymph node was 4.0 [25^{th} – 75^{th} centile, 3.5-5.6]. The largest enlarged lymph node on T2-weighted images of post-vaccination MRI demonstrated a higher relative signal intensity than the corresponding lymph node on T2-weighted images of pre-vaccination MRI ($p = 0.002$). The median ADC of enlarged lymph nodes was 1.1 x 10^{-3} mm^2/sec with the range 0.6 – 2.0 x 10^{-3} mm^2/sec in this study, and thus ADC remained within the normal range.

We observed an overall prevalence of COVID-19 vaccination-related axillary lymphadenopathy of 21%. The prevalence of lymphadenopathy in participants at 1-14, 15-28, 29-42, and 43-56 days after vaccination were 65%, 40%, 29%, and 18%, respectively. Wolfson et al. also recently evaluated the number of patients with and without lymphadenopathy in terms of days after vaccination and observed a high prevalence of lymphadenopathy early after vaccination (6). The prevalence ranged from 3 to 44% in other studies (6, 11, 14, 15). Differences likely relate to the study population, the definition of lymphadenopathy, time delay after vaccination and method to evaluate lymphadenopathy.

Given the rate of decrease of lymphadenopathy over 29-56 days, postponing nonurgent imaging examinations of the chest is recommended (2-4). In particular at 1-14 days after vaccination, a high prevalence of lymphadenopathy may cause many false positives for malignancy and heighten anxiety of examinees. Recommendations and guidelines should be revised for more appropriate duration of postponement and follow-up strategies based on accumulated knowledge including our results.

Participants with lymphadenopathy were younger than those without lymphadenopathy in this study. This is compatible with the clinical trial of the Moderna vaccine (17) and recent report by Horvat et al. (15).

Lymphadenopathy was significantly more common in females than in males. This is

compatible with the previous study by Nishino et al. (11). This female predominance may indicate that females are more hypersensitive to COVID-19 vaccines, just as females are more likely to develop delayed localized cutaneous reactions to the Moderna vaccine (so-called "Moderna arm") and hypersensitivity to other vaccines (18, 19).

Lymphadenopathy was more common in those who received the Moderna vaccine than in those who received the Pfizer-BioNtech vaccine. This is also compatible with the clinical trials (17, 20) and previous imaging studies (6, 11).

We defined axillary lymphadenopathy as the presence of at least one enlarged axillary lymph node on post-vaccination MRI that was larger than the corresponding lymph node on pre-vaccination MRI. It is acknowledged that a single definition for lymphadenopathy is not widely agreed on (2). Because the prevalence and imaging characteristics depend on the definition of lymphadenopathy, we explicitly defined lymphadenopathy before we started the study. To detect true enlargement of lymph nodes, intraindividual comparison of cross-sectional images from two time points is the best method. We did not evaluate lymph nodes with a short-axis diameter < 5 mm, because they were too small to be evaluated properly considering the spatial resolution of MRI, especially DWI.

Enlarged lymph nodes demonstrated a higher signal intensity on T2-weighted images from post-vaccination MRI. It presumably reflects an increase in water content due to immune reactions. A high signal intensity on T2-weighted images is not specific, and it may be limited in the differentiation of COVID-19 vaccination-related axillary lymphadenopathy from malignant lymphadenopathy.

The median ADC of enlarged lymph nodes in our study was 1.1 x 10^{-3} mm^2/sec, with a range of 0.6 – 2.0 x 10^{-3} mm^2/sec. Donners et al. investigated ADC of normal lymph nodes (21). According to their data, the median ADC of normal axillary lymph nodes is approximately 1.1 x

10^{-3} mm^2/sec, with a range of 0.7 – 1.8 x 10^{-3} mm^2/sec. Other studies showed that ADC of metastatic axillary lymph nodes in patients with breast cancer was lower than that of benign axillary lymph nodes (16, 22, 23). Therefore, ADC of enlarged lymph nodes induced by vaccination remained within the normal range and expected to be helpful in differentiating COVID-19 vaccination-related axillary lymphadenopathy from malignant lymphadenopathy. The change in ADC may also be informative for differential diagnosis.

There are limitations of this study. Our study was conducted at a single institution in Japan, and most participants were of Asian ethnicity. Only mRNA vaccines were included (Pfizer-BioNtech or Moderna). Study participants were relatively old as seniors were prioritized for COVID-19 vaccinations in Japan. Only a subset of participants underwent evaluation of the changes in signal intensity on T2-weighted images and ADC of enlarged lymph nodes between pre-vaccination and post-vaccination MRI.

In conclusion, the prevalence of COVID-19 vaccination-related axillary lymphadenopathy in participants 1-14 days after vaccination was 65% with decreased prevalence over 4-8 weeks. Younger age, female sex, and Moderna vaccine were predisposing factors. Enlarged lymph nodes demonstrated a higher signal intensity on T2-weighted images, while ADC remained within the normal range. These results provide important information needed to establish evidence-based guidelines for conducting proper follow-up and final assessment of axillary lymphadenopathy after COVID-19 vaccination and avoiding unnecessary imaging and invasive procedures.

Acknowledgments

We thank the staff members of the Department of Computational Diagnostic Radiology and Preventive Medicine, The University of Tokyo Hospital for their contribution to conducting the comprehensive health screening program and recording clinical data carefully.

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Table: Background characteristics of participants with and without COVID-19 vaccination-related axillary lymphadenopathy

Characteristics	Overall (n = 433)	With lymphadenopathy (n = 90)	Without lymphadenopathy (n = 343)	*p* value
Age (years)	65 ± 11	61 ± 10	66 ± 10	$p < 0.001$
Sex				$p = 0.005$
Male	300	51	249	
Female	133	39	94	
Type of vaccine				$p = 0.003$
Pfizer-BioNtech	390	73	317	
Moderna	43	17	26	
Days after second vaccination	56 [30-90]	24 [12-42]	67 [42-96]	$p < 0.001$
Days between pre-vaccination and post-vaccination MRI	364 [339-456]	357 [336-492]	364 [341-452]	$p = 0.42$

Continuous variables are presented as means ± standard deviation for normally distributed data and medians and [25^{th} – 75^{th} centiles] for non-normally distributed data as appropriate. For continuous variables, the Wilcoxon rank sum test was used to compare the medians of two groups. For categorical variables, the Fisher's exact test was used to compare two groups.

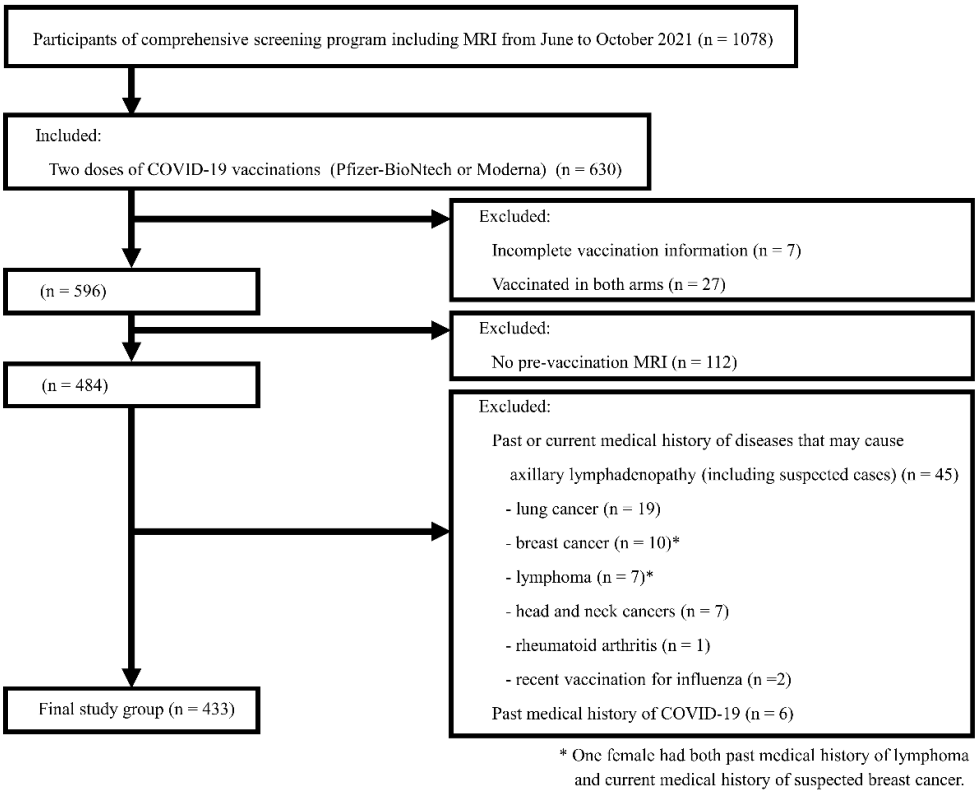


Figure 1: Flow chart for enrollment.

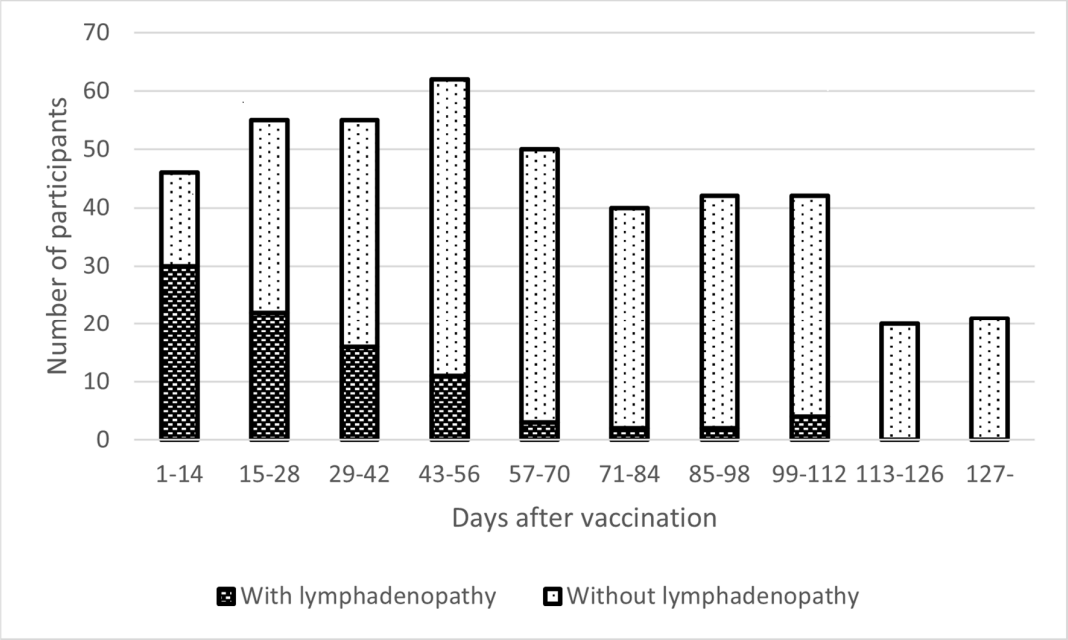
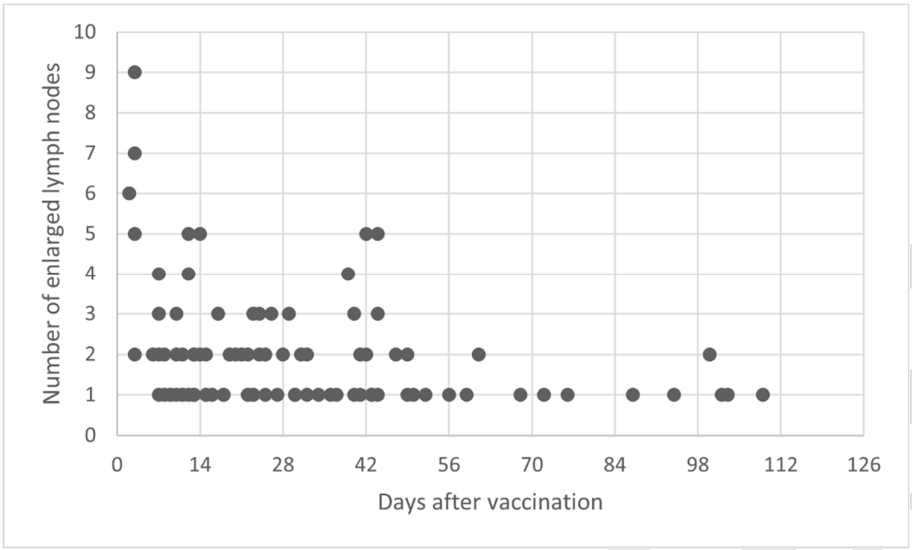
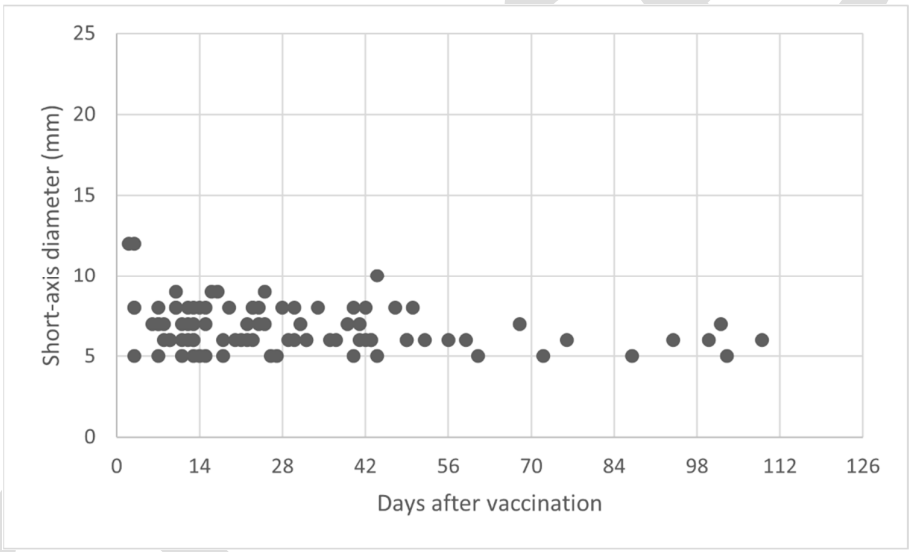


Figure 2: Bar chart shows number of participants with and without COVID-19 vaccination-related axillary lymphadenopathy versus days after the second vaccination. The prevalence of COVID-19 vaccination-related axillary lymphadenopathy in participants at 1-14, 15-28, 29-42, and 43-56 days after vaccination were 65%, 40%, 29%, and 18%, respectively. The prevalence of lymphadenopathy was lower than 10% more than 56 days after vaccination.

A


Number of enlarged lymph nodes
0
1
2
3
4
5
6
7
8
9
10
0
14
28
42
56
70
84
98
112
126
Days after vaccination

B


Short-axis diameter (mm)
0
5
10
15
20
25
0
14
28
42
56
70
84
98
112
126
Days after vaccination

C

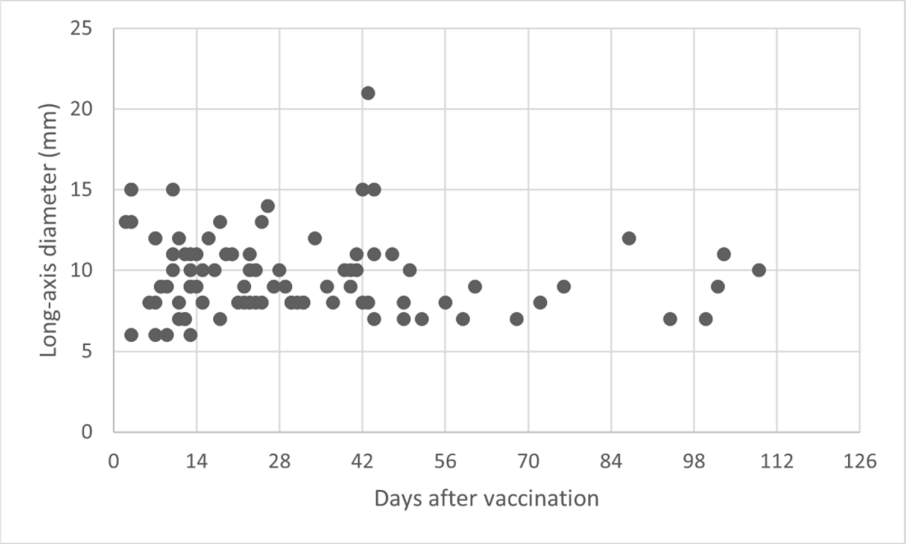
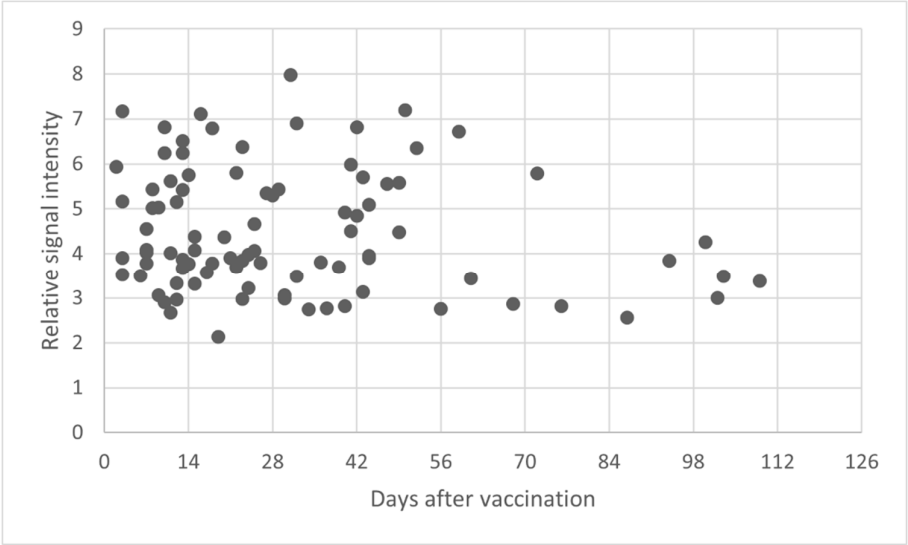
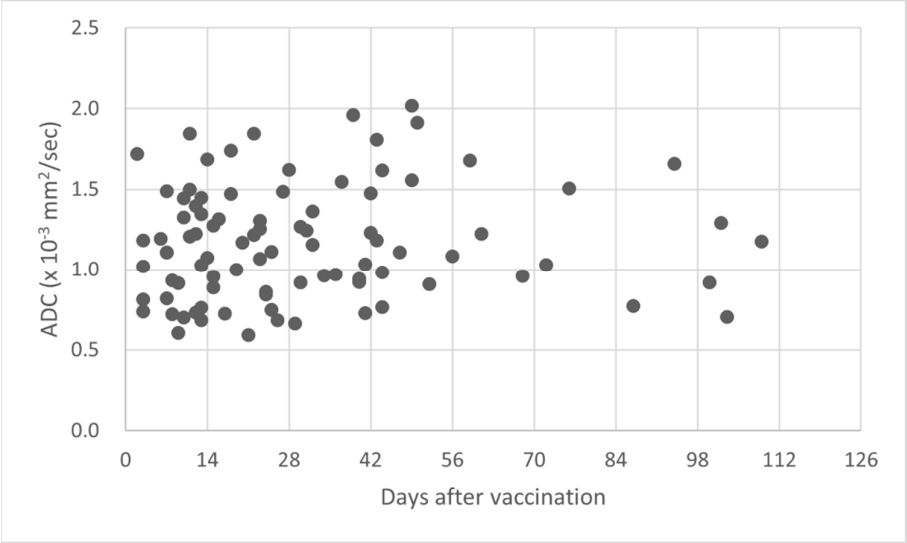


Figure 3: (A) Scatterplot of the number of enlarged lymph nodes versus days after COVID-19 vaccination. Five or more enlarged lymph nodes were noted in eight of the 433 participants (2%), and those in six of the eight participants were noted 1-14 days after vaccination. (B) Scatterplot of the short-axis diameter of the largest enlarged lymph node versus days after COVID-19 vaccination. Only four of the 433 participants (1%) had enlarged lymph nodes ≥ 10 mm in the short axis. (C) Scatterplot of the long-axis diameter of the largest enlarged lymph node versus days after COVID-19 vaccination.

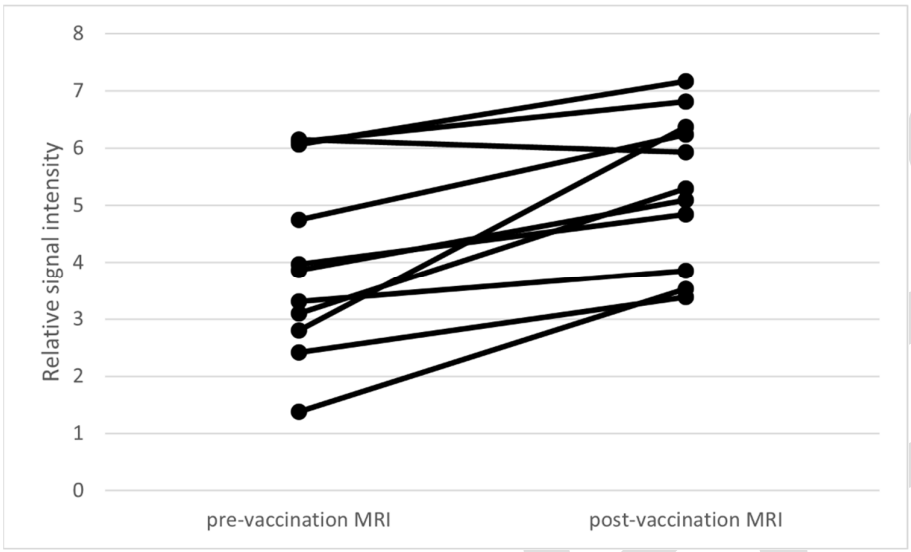
A


Relative signal intensity
0
1
2
3
4
5
6
7
8
9
0
14
28
42
56
70
84
98
112
126
Days after vaccination

B


ADC (x 10-3 mm2/sec)
0.0
0.5
1.0
1.5
2.0
2.5
0
14
28
42
56
70
84
98
112
126
Days after vaccination

C


Relative signal intensity
8
7
6
5
4
3
2
1
0
pre-vaccination MRI
post-vaccination MRI

D

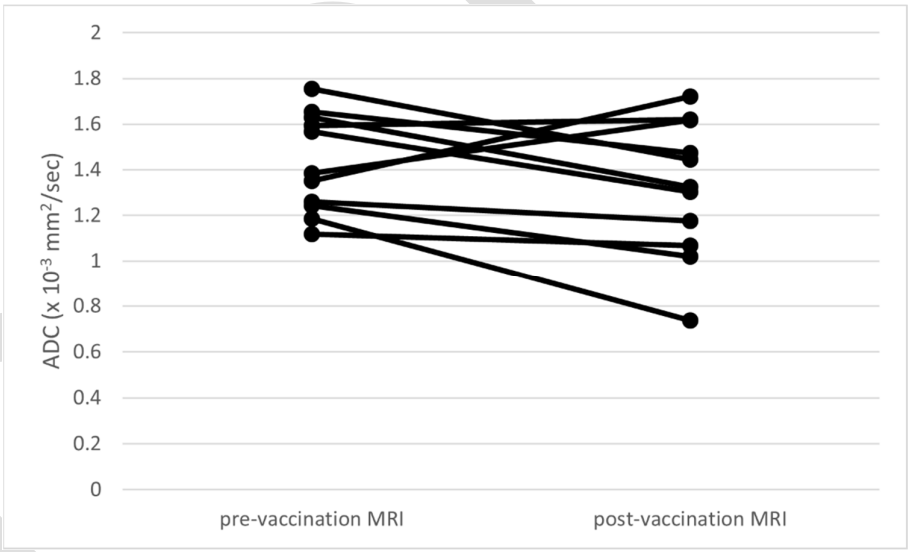
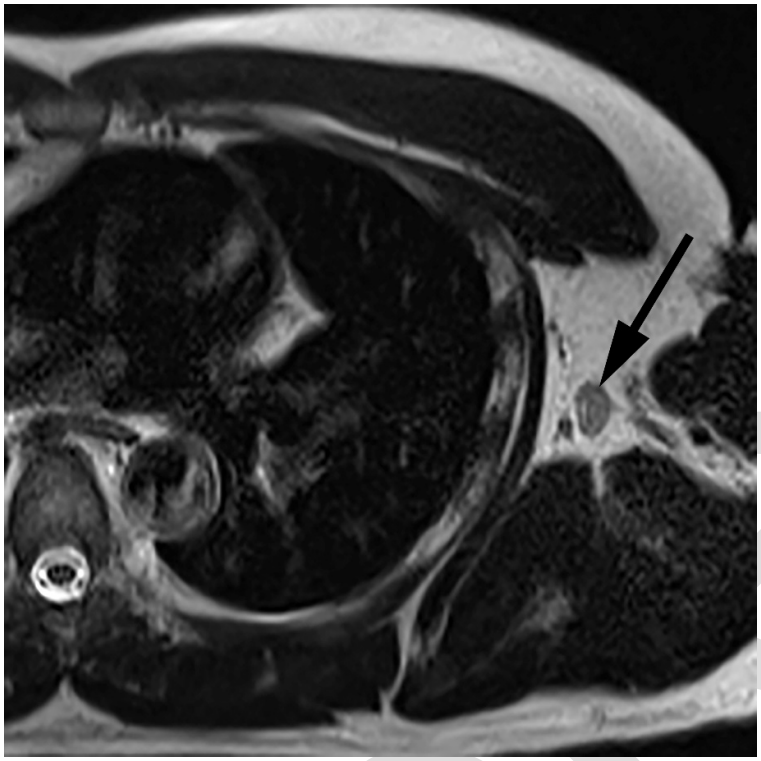
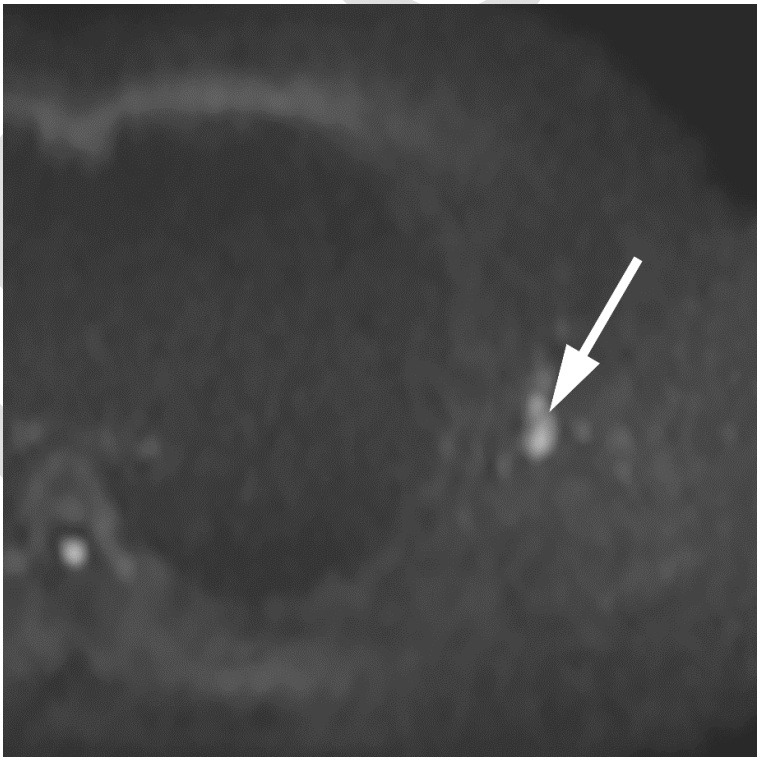

ADC (x 10-3 mm2/sec)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
pre-vaccination MRI
post-vaccination MRI

Figure 4: (A) Scatterplot of the relative signal intensity on T2-weighted image (T2WI) of the largest enlarged lymph node versus days after COVID-19 vaccination. The relative signal intensity was calculated by dividing the signal intensity of the lymph node by the signal intensity of the pectoralis minor muscle. (B) Scatterplot of the apparent diffusion coefficient (ADC) of the largest enlarged lymph node versus days after COVID-19 vaccination. (C) Graph shows changes in the relative signal intensity on T2-weighted images of the largest enlarged lymph node between pre-vaccination and post-vaccination MRI in the 11 participants. The largest enlarged lymph node on T2-weighted images from post-vaccination MRI demonstrated a higher relative signal intensity than the corresponding lymph node on T2-weighted images from pre-vaccination MRI ($p = 0.002$). (D) Graph shows changes in ADC of the largest enlarged lymph node between pre-vaccination and post-vaccination MRI in the 11 participants. The changes in ADC demonstrated the absence of a pattern ($p = 0.17$).

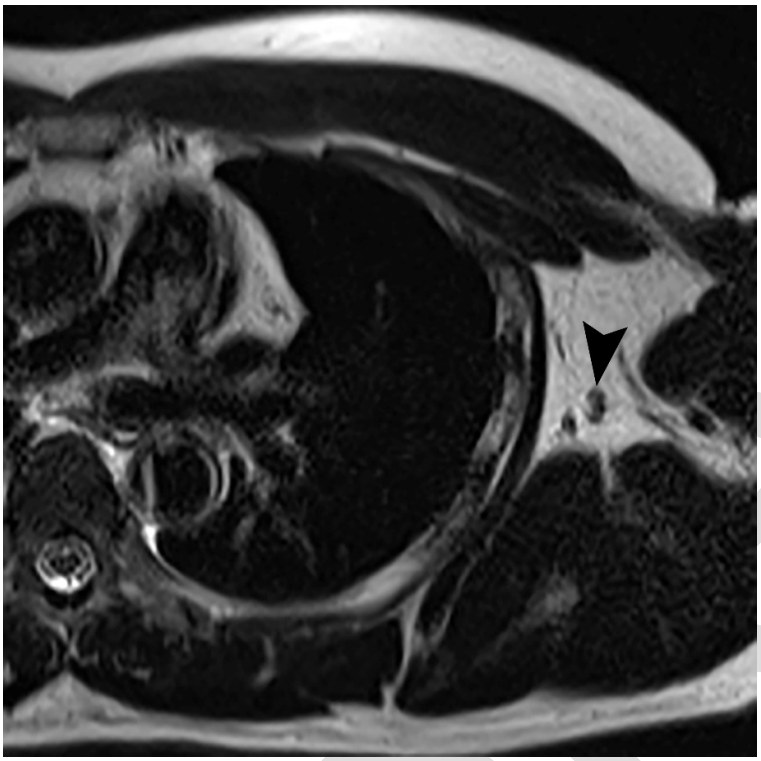
A



B



C



D

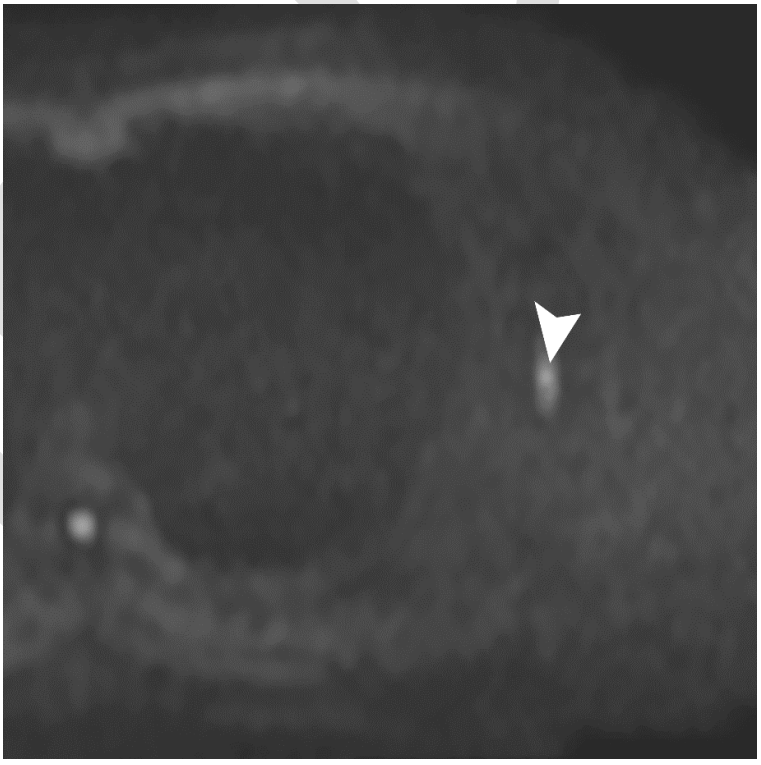
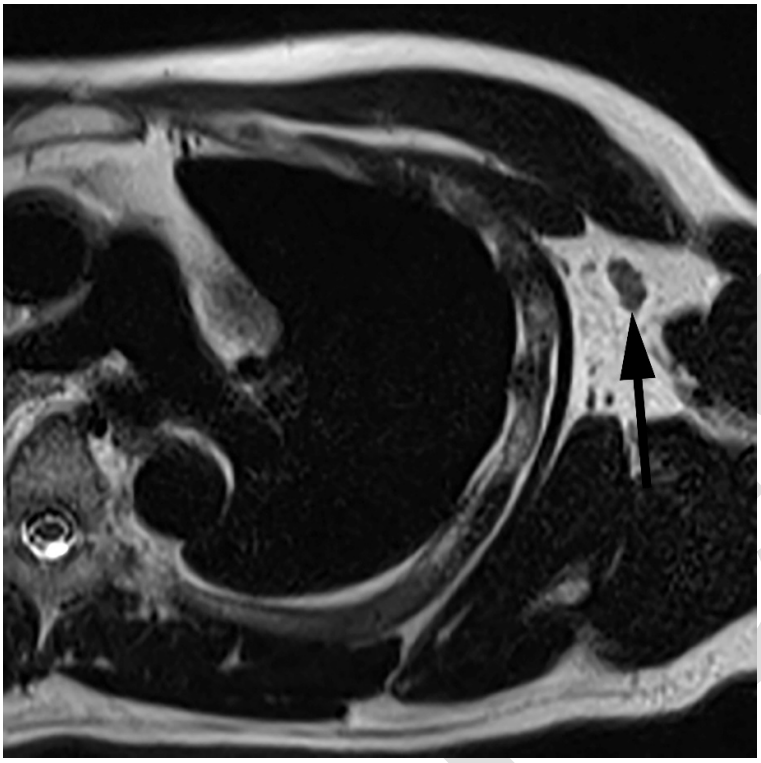
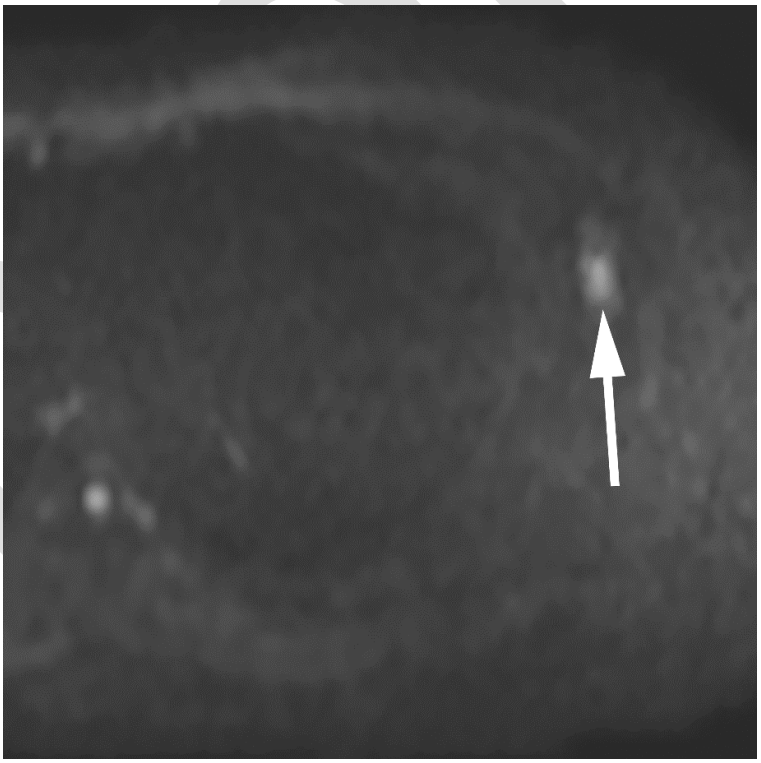


Figure 5: Images in a 50-year-old man 10 days after COVID-19 vaccination. (A, B) Axial T2-weighted image (A) and diffusion-weighted image (DWI) (B) obtained at post-vaccination MRI demonstrate an enlarged lymph node (arrows) in the left axilla ipsilateral to the vaccinated site. (C, D) Axial T2-weighted image (C) and DWI (D) obtained at pre-vaccination MRI demonstrate the corresponding lymph node (arrowheads). The enlarged lymph node on post-vaccination MRI scans is obviously larger than the corresponding lymph node on pre-vaccination MRI scans. The enlarged lymph node on the T2-weighted image at post-vaccination MRI demonstrates a higher signal intensity than the corresponding lymph node on T2-weighted image at pre-vaccination MRI.

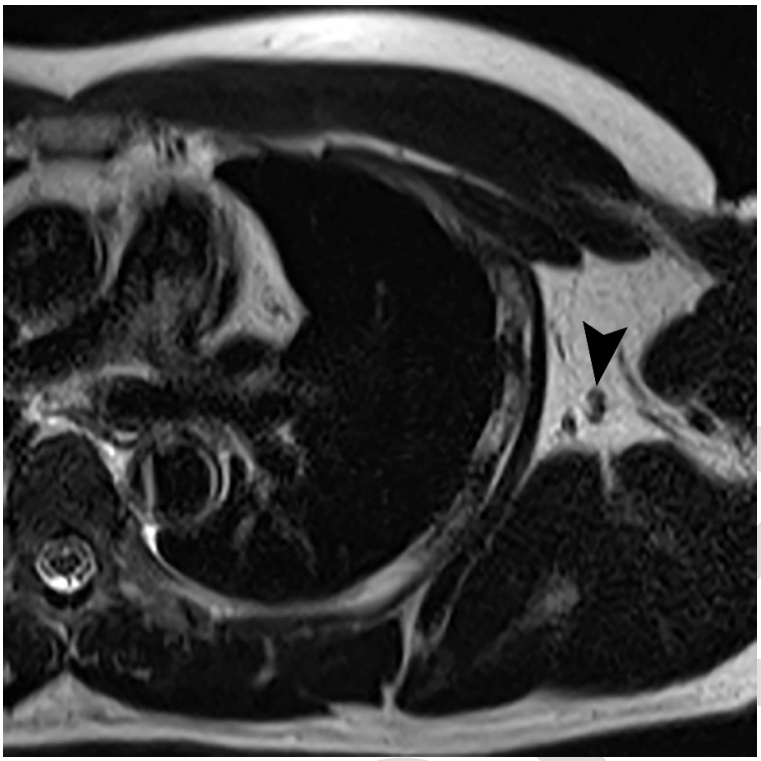
A



B



C



D

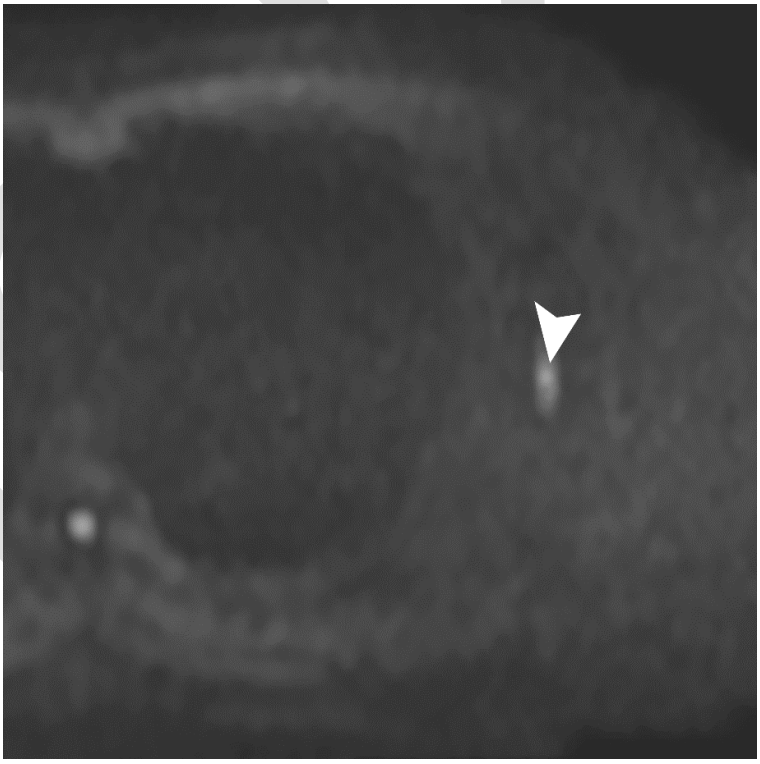


Figure 6: Images in a 53-year-old man 42 days after COVID-19 vaccination. (A, B) Axial T2-weighted image (A) and diffusion-weighted image (DWI) (B) obtained at post-vaccination MRI demonstrate an enlarged lymph node (arrows) in the left axilla ipsilateral to the vaccinated site. (C, D) Axial T2-weighted image (C) and DWI (D) obtained at pre-vaccination MRI demonstrate the corresponding lymph node (arrowheads). The enlarged lymph node on post-vaccination MRI scans is larger than the corresponding lymph node on pre-vaccination MRI scans. In this participant, the enlarged lymph node on the T2-weighted image at post-vaccination MRI demonstrates iso-intensity to the corresponding lymph node on T2-weighted image at pre-vaccination MRI.