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Lymphadenopathy subsequent to Covishield (ChAdOx1 nCoV-19) Corona virus vaccine: ultrasound findings and clinical implications

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Abstract

Introduction: Post anti-COVID-19 vaccine lymphadenopathies have been recently described in literature, from different parts of the world. Although there have been studies on lymphadenopathy following mRNA vaccines, there is a paucity of studies on lymphadenopathy following inactivated viral vaccines, such as Covishield.

Aim: In this study, we explored lymphadenopathy subsequent to Covishield vaccine in terms of its various ultrasound parameters in the Indian population.

Methods: This hospital-based longitudinal study was conducted among 50 adult beneficiaries of Covishield vaccine. Sociodemographic details and relevant clinical history were recorded using a semi-structured performa. Detailed ultrasound (USG) examination of the bilateral axillae was done on the day of vaccination and after 6–12 days post vaccination. Vaccine beneficiaries were evaluated for the presence of any vaccine-associated lymphadenopathy and described the presence, number, size, morphology, cortical thickness, and presence or absence of echogenic hilum.

Results: Out of total (63) lymph nodes evaluated sonologically, majority (80.9%) of lymph nodes showed the features of benign lymphadenopathy. However, 12.6% (8/63) lymph nodes showed diffusely thickened cortex with preserved central echogenic hilum, 4.76% (3/63) lymph nodes showed eccentric cortical thickness with preserved hilar pattern, while only one lymph node showed diffuse cortical thickening with loss of central echogenic hilum.

Conclusion: With an increase in vaccination coverage, clinicians are likely to confront increasing cases of vaccine-associated axillary lymphadenopathy. Therefore, they should exercise care, that contemporary anti-COVID-19 vaccination can present an aetiology of axillary lymph nodes with suspicious USG features.

Keywords: COVID-19, Covishield, vaccine lymphadenopathy, ultrasound

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Introduction

In December 2019, a group of pneumonia-like cases were reported from Wuhan in Hubei province, China. This novel virus based on the phylogeny was named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) and the resultant disease as coronavirus disease (COVID-19).[1] Since then, it has continued spread unabated at a rapid pace throughout the world in multiple phases. The first case of COVID-19 was reported in India on 30 January 2020, in a medical student who had a travel history from Wuhan, China.[2]

As the cases surged, it caused unprecedented public health crisis overwhelming the public health system of India. Initially, non-pharmacological interventions were the mainstay for the control of disease. However, in due course of time, the genomic sequencing of this novel virus

was carried out, and the development of vaccines was undertaken on a priority basis. Within a short span of time, a number of candidate vaccines were available for public use, making the emergency use of anti-COVID-19 vaccines, the fastest rollout of vaccines for a disease in the history of mankind.[3]

The initial vaccines which were in the fray were mRNA vaccines by Pfizer and Moderna, Oxford-AstraZeneca Covishield (ChAdOx1 nCoV-19 or AZD1222), and Gamaleya Research Institute of Epidemiology and Microbiology (Sputnik V) introduced in different parts of the world.[4,5] In India, Covishield and indigenously developed Covaxin (BBV152) were the vaccines which were predominantly used. Vaccination drive against COVID-19 was launched in India on 16 January 2020.[6] Till 31 March 2022, 11.35 billion doses of vaccines have been given around the world. India alone by this period, has completed 1.84 billion doses of vaccines. Subsequent to the use of anti-COVID-19 vaccines for public use, there have been some cases of lymphadenopathy reported. Moreover, present-day studies have reported cases of unilateral axillary and supraclavicular adenopathy associated with various anti-COVID-19 vaccines. Lymphadenopathy has been reported as 0.3% and 1.1% of Pfizer-BioNTech and Moderna vaccines, respectively.[7,8] As vaccination has progressed, there have been increased instances of regional adenopathy reported, as an incidental finding in different imaging modalities. Ultrasound (USG) examination represents the first-line imaging method due to its speed, availability, low cost and repeatability.[9,10] Incidentally detected post anti-COVID-19 vaccine in supraclavicular and axillary lymph nodes may imitate pathological lymph nodes.

Although there have been studies on lymphadenopathy following mRNA vaccines, there is a dearth of studies on lymphadenopathy following inactivated viral vaccines, such as Covishield. To the best of our knowledge, there have been no studies in this regard in the Indian population. Therefore, in this study, we explored lymphadenopathy subsequent to Covishield vaccine in terms of its various USG parameters. We evaluated vaccine beneficiaries for the presence of any vaccine-associated lymphadenopathy and described the presence, number, size, morphology, cortical thickness, and presence or absence of echogenic hilum.

Methodology

Study population and setting

This is a hospital-based longitudinal study conducted in the month of August 2021 at the radiology department of a tertiary medical institution in North India. We included 50 recipients of Covishield vaccine who gave their consent for the study and satisfied the inclusion and exclusion criteria. Systematic random sampling was followed for the selection of the study participants and every 10th beneficiary who underwent vaccination at the Covid vaccination centre of the institute was screened for eligibility and included after written informed consent.

Inclusion and exclusion criteria

Adult beneficiaries coming for Covishield vaccine were included according to the sampling strategy after briefing them about the study process and procedures and taking consent. Adults with significant axillary lymphadenopathy detected by USG on the day of vaccination or with the history of any malignancy or pulmonary/systemic disease which could result in axillary lymphadenopathy, were excluded. In case the 10th person did not satisfy the eligible criteria, the next beneficiary was assessed for eligibility, and included. The process was continued till the recruitment of the study participants was completed. Sociodemographic details and relevant clinical history were recorded using a semi-structured performa.

Imaging modality

USG was performed using Alpinion E-cube i7 machine. Patient was positioned supine on the examination table. Detailed examination of the bilateral axillae was done on the day of vaccination and after 6–12 days post vaccination. USG images of each patient were assessed for the presence and level of lymph nodes, their number, size, morphology, cortical thickness, and the presence or absence of echogenic hilum. All necessary protocols were adhered to during the procedure.

Statistical analysis

Data were entered into MS Excel and analysed using IBM SPSS Statistics for Windows, Version 20.0 (IBMCorp., Armonk, NY). Frequency was expressed using proportion and percentages.

Normally distributed data were presented as mean (±SD), and categorical variables as frequency (%). Categorial variable (lymphadenopathy) was compared with the sociodemographic variables using Chi-square test/ Fisher's exact test. A *p*-value was assessed at significance level of less than 0.05.

Ethical permission

The study was approved by the Institute Ethics Committee vide letter number IEC/AIIMS/BTI/133. All necessary protocols were adhered to and confidentiality was maintained throughout the study. Participants were briefed about the objectives of the study before being enrolled in the study, and informed written consent was taken.

Results

A total of 50 beneficiaries were included in the study and 63 lymph nodes in total were evaluated. Participants were near equally distributed in the youngest (18–30 years) 18 (36%) and elderly 19 (38%) years age group. About three-fourths, 38 (76%) of the participants were males. Five beneficiaries had a previous positive history (at least 3 months before) of Covid infection. Nearly two-thirds 32 (64%) of the participants had associated comorbidities (hypertension, diabetes, obesity, and liver disease). However, 11 (22%) of the study participants reported lymphadenopathy on the day of vaccination. Majority, 38 (76%) of the participants were diagnosed with lymphadenopathy on USG 1 week following vaccination. Among those in whom lymphadenopathy was found, majority 25 (65.7%) showed multiple lymph nodes (Table 1).

Out of total (63) lymph nodes evaluated sonologically, majority (80.9%) of lymph nodes showed features of benign lymphadenopathy, that is, well-defined oval shape, uniformly thin cortex with preserved central echogenic hilum which formed bulk of the node [Figure 1(a)]. About 12.6% (8/63) lymph nodes showed diffusely thickened cortex with preserved central echogenic hilum [Figure 1(b)], 4.76% (3/63) lymph nodes showed eccentric cortical thickness with preserved hilar pattern [Figure 1(c)] while only 1.5% (1/63) of lymph nodes showed diffuse

Table 1. Frequency distribution of the characteristics of vaccinated individuals in the study (*N* = 50).

Variable	*N* (%)
Age group (years)	
18–30	18 (36)
31–60	13 (26)
>60	19 (38)
Sex	
Male	38 (76)
Female	12 (24)
History of COVID-19 infection	
Yes	5 (10)
No	45 (90)
Comorbidities	
Yes	18 (36)
No	32 (64)
Lymphadenopathy (reactive) on the day of vaccination	
Yes	11 (22)
No	39 (78)
Lymphadenopathy after 1 week of vaccination	
Yes	38 (76)
No	12 (24)
Multiple lymphadenopathy(*n* = 38)	
Yes	25 (65.7)
No	13 (34.3)
Lymph node characteristics on USG (*n* = 63)	
Oval with uniformly thin cortex and preserved echogenic hilum	51 (80.9)
Diffuse cortical thickening with preserved echogenic hilum	8 (12.69)
Diffuse cortical thickening with loss of central echogenic hilum	1 (1.58)
Eccentric cortical thickness with preserved echogenic hilum	3 (4.76)

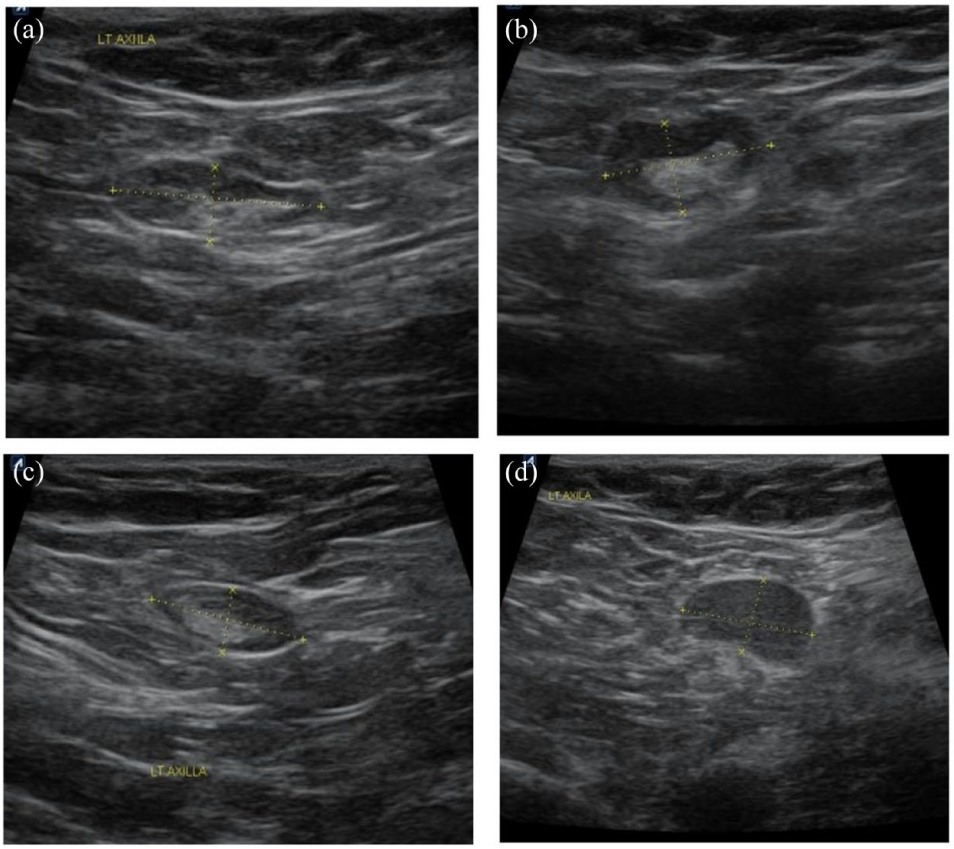

Figure 1. (a) USG of left axilla of a 65-year-old female 1 week after vaccination. The lymph node shows features of benign reactive lymph node, that is, well-defined oval shape, uniformly thin hypoechoic cortex and central echogenic hilum. (b) A 20-year-old male 12 days after vaccination showing well-defined oval axillary lymph node with diffusely thickened cortex. However, central echogenic hilum is preserved. (c) A 48-year-old female showing axillary lymph node 10 days after vaccination. The lymph node is well-defined oval; however, it shows eccentrically thickened cortex indenting the underlying echogenic hilum. (d) USG of left axilla of 52-year-old male 10 days after vaccination shows lymph node with suspicious features, that is, thickened cortex with loss of central echogenic hilum.

cortical thickening with loss of central echogenic hilum [Figure 1(d)].

On univariate analysis, using Chi-square/Fisher's exact test, only lymphadenopathy (benign/reactive) on the day of vaccination was found to be significantly associated with the presence of lymphadenopathy status post vaccination ($p = 0.04$) (Table 2).

Discussion

Association of anti-COVID-19 vaccines with ipsilateral axillary lymphadenopathy is being increasingly described in literature. Conventionally, this vaccine is administered intramuscularly in left deltoid muscle. Axillary lymph nodes receive lymphatic drainage from ipsilateral breast, arm, thoracic wall and upper abdominal wall. Thus, any infective, inflammatory or mitotic aetiology involving the draining sites may result in ipsilateral axillary lymphadenopathy. Migration of locally activated antigens from injection site to draining lymph nodes results in vaccine-associated lymphadenopathy.[11] These enlarged lymph nodes may be detected incidentally on screening or follow-up imaging of cancer patients. Whether these lymph nodes are benign or malignant pose a great diagnostic dilemma for clinicians and radiologists, thereby having a substantial impact on patient management strategy.

Table 2. Association between lymphadenopathy and other variables.

Variable	Lymphadenopathy present	Lymphadenopathy absent	*p* value
Age group (in years)			0.63
18–30	15	3	
31–60	9	4	
>60	14	5	
Sex			0.49
Male	28	10	
Female	10	2	
History of COVID-19 infection			0.37
Yes	3	2	
No	35	10	
Comorbidities			0.82
Yes	14	4	
No	24	8	
Lymphadenopathy on the day of vaccination			**0.04***
Yes	11	0	
No	27	12	

*Significant, Fisher's exact value.

USG is the modality of choice for evaluating axillary lymph nodes due to its high sensitivity and specificity.[12] Various morphological features of lymph nodes have been described to distinguish benign *versus* malignant lymph nodes. Normal or benign lymph nodes show oval or lobulated shape with uniformly thin hypoechoic cortex measuring less than 3 mm in thickness.[13] Benign lymph nodes show central echogenic hilum. Increase in lymph node size (>2 cm), round shape, loss of central fatty hilum and diffuse or focal cortical thickness >3 mm predict malignancy as cause of lymphadenopathy.[14–16]

In literature, axillary lymphadenopathy as a side effect of vaccination, has been reported previously in few recipients of Bacillus Calmette-Guerin, influenza and human papilloma virus vaccine.[17–19] Although the mRNA vaccines being used against COVID-19 are safe, but they are associated with few side effects. The most common side effect includes pain at injection site, fever, tiredness, headache and ipsilateral axillary lymphadenopathy.[20–22] Axillary swelling ipsilateral to injection site has been reported in 11.6% and 16% of patients receiving first and second dose of Moderna COVID-19 vaccine.[23] Incidence of ipsilateral axillary lymphadenopathy has been reported to be <1% for Pfizer-BioNTech and AstraZeneca vaccine and 0.1% for Janssen vaccine.[8,24,25]

In our study, about 76% of patients showed ipsilateral axillary lymphadenopathy and 65.7% showed multiple lymph nodes. We found lymphadenopathy in every age group similar to study by Cocco *et al.*, while another study reported increased incidence in younger age group (<40 years).[17,26] In the study by Cocco *et al.*, evaluating the multiparametric USG findings of

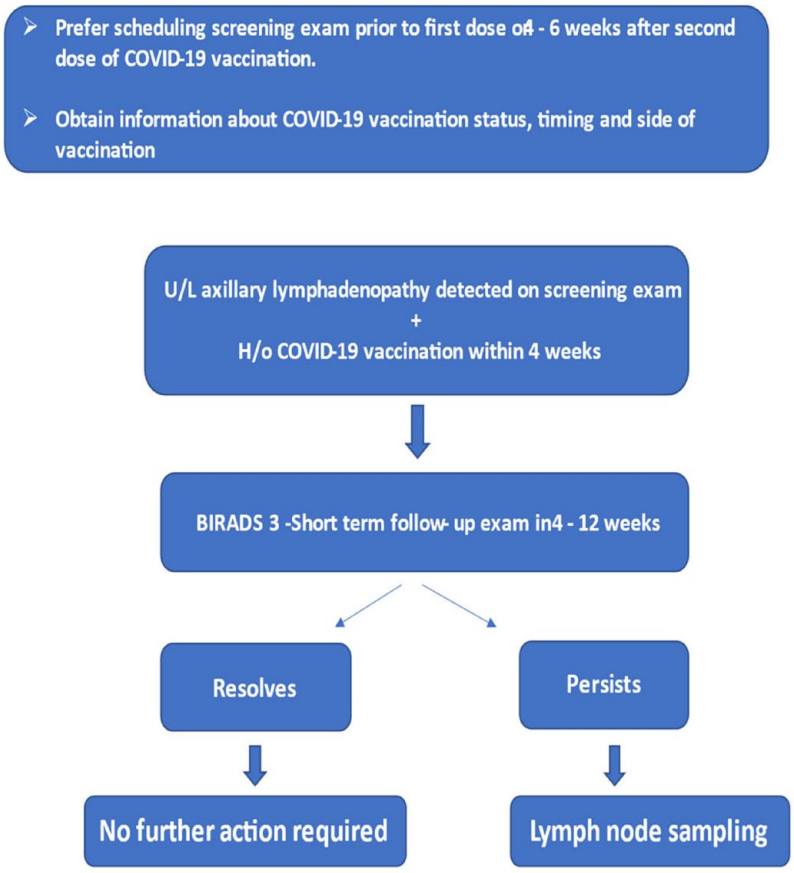

Figure 2. Recommendations for management of axillary lymphadenopathy in patients with recent COVID-19 vaccination by the Society of Breast Imaging.

COVID vaccine-associated lymphadenopathy in 24 patients, 11 (45.8%) showed ipsilateral axillary lymphadenopathy and 13 patients (54.2%) showed supraclavicular lymphadenopathy. Majority of the patients (75%) showed benign lymph node features, while 37.5% of patients showed asymmetric cortical thickness.[17] Granata *et al.*[27] also demonstrated varying USG appearances of vaccine-associated lymphadenopathy. A study from the United States by Mortazavi *et al.*[28] revealed lymph nodes with diffuse or focal cortical thickening in 29 (42.6%) cases and preserved hilar fat in one case. Necrotic lymph node appearing hypoechoic with loss of blood flow has been described in a single case.[29] Apart from the common nodal sites (axillary, supraclavicular), there have been reports of lymphadenopathy in atypical sites (infraclavicular, pectoralis major and nuchal) in a study by Cocco *et al.*[30] It can be attributed to a robust immune system spreading along the lymphatics. They should be evaluated with concern in high-risk patients with history of neoplasia, to avoid misdiagnosis.

Apart from USG, anti-COVID-19 vaccine-associated lymphadenopathy has also been detected on other imaging modalities, such as mammography,[28,31,32] breast MRI[29,32–34] and[18] F-FDG-PET/CT[32,33,35–42] posing a diagnostic conundrum.

According to fifth edition of BI-RADS, isolated unilateral axillary lymphadenopathy detected on screening mammography in the absence of history of any infectious/inflammatory cause is categorised as BI-RADS 0 and warrants additional imaging evaluation.[43] In the absence of any infectious or inflammatory source in ipsilateral breast, it is categorised as BI-RADS 4 and warrants biopsy evaluation. Such increased incidence of vaccine-associated axillary lymphadenopathy has not been reported with any vaccination till date. Most subclinical cases of unilateral axillary

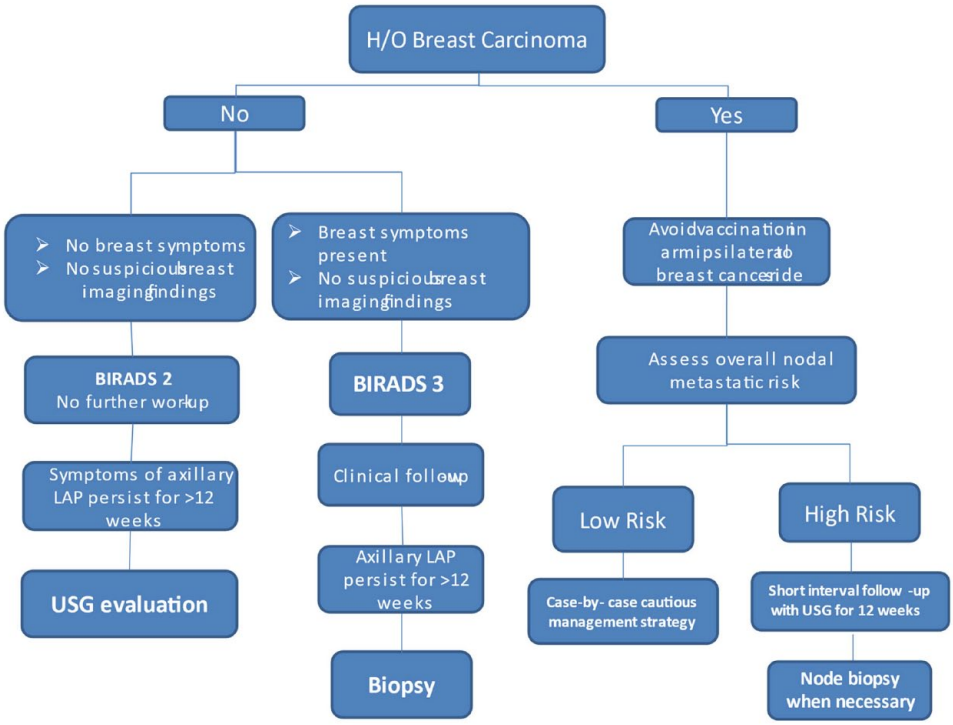

Figure 3. Recommendations for the management of axillary lymphadenopathy in patients with recent COVID-19 vaccination by European Society of Breast Imaging.

lymphadenopathy following anti-COVID-19 vaccination has been described in patients undergoing breast imaging.[44,45] Therefore, this has led to subsequent recommendations from breast imaging societies. Society of Breast Imaging has given recommendations for the management of axillary lymphadenopathy in patients with recent anti-COVID-19 vaccination (Figure 2).[46] Similar guidelines have been issued by European Society of Breast Imaging (Figure 3). It emphasises vaccine to be given in the contralateral arm or anterolateral thigh in patients with history of breast cancer.[47]

The published literature so far is based on the clinical findings of axillary lymphadenopathy. Not all vaccine-associated axillary lymphadenopathy could be clinically evident so the incidence of vaccine-associated ipsilateral axillary lymphadenopathy would be much higher. Also, with the addition of third/booster dose, the cases of lymphadenopathy after vaccination are expected to rise. However, postvaccination lymphadenopathy may not pose significant concern to vaccinated individuals and should not deter the vaccination drive. However, they need to be kept in consideration, particularly in follow-up of malignancy patients.[48] Clinicians must be vigil about the transient hypermetabolic regional lymph nodes and should evaluate the detailed vaccination history, without fail. Since most of these lymphadenopathies resolve spontaneously within 2 weeks, imaging modalities can be undertaken 4–6 weeks following vaccination as suggested by other studies.[46,49] Observation for at least 6 weeks until resolution or short-term follow-up with USG with reassurance is recommended rather than immediate biopsy and change in treatment course, unless the patient has a medical emergency.

Strengths and limitations of the study

The single centre study with limited sample size and absence of long-term follow-up is one of the

critical limitations of the study. Also, pathological correlation was not established in our study. Nevertheless, to our knowledge, this is the first study in the Indian population evaluating lymphadenopathy subsequent to an inactivated anti-COVID-19 vaccine, Covishield. Even subclinical cases of lymphadenopathy were detected and characterised sonologically. This study adds to the growing body of literature about incident lymphadenopathy following anti-COVID-19 vaccinations that will guide clinicians in the management of patients, both with oncological disease and with patients with recently developing lymphadenopathy. Furthermore, prospective studies with a longer follow-up time and multicentric in approach can further substantiate the findings of our study.

Conclusion

With mass roll out of anti-COVID-19 vaccine and administration of booster doses, clinicians are likely to confront increasing cases of vaccine-associated axillary lymphadenopathy. Clinicians should exercise care, that a history of a recent anti-COVID-19 vaccine can present as an aetiology of axillary lymph nodes with suspicious USG features. Information regarding the vaccine type, site, dose and duration since vaccination should be collected prior to imaging. Patients with suspicious imaging findings should be kept on follow-up. Information regarding vaccine-associated lymphadenopathy should be disseminated to allay the recipient's and clinician's anxiety and avoid unnecessary biopsies, especially in cancer patients.

Declarations

Ethical approval and consent to participate

Ethical approval was obtained from the Institute Ethics Committee of AIIMS Bathinda, Punjab, India vide letter number IEC/AIIMS/BTI/133. Participants were briefed about the objectives of the study before being enrolled in the study, and informed written consent was taken.

Consent for publication

Not applicable.

Author contributions

Soumya Swaroop Sahoo: Formal analysis; Methodology; Supervision; Validation; Writing – review & editing.

Navdeep Kaur: Conceptualisation; Formal analysis; Investigation; Project administration; Resources; Software; Supervision; Writing – original draft; Writing – review & editing.

Amandeep Kaur: Conceptualisation; Formal analysis; Methodology; Writing – review & editing.

Shivane Garg: Investigation; Project administration; Software.

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Competing interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Availability of data and materials

All the data supporting the findings of the study is available in form of tables and images within the article.

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References

1. Li Q, Guan X, Wu P, *et al*. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med* 2020; 382: 1199–1207.
2. Chowdhury SD and Oommen AM. Epidemiology of COVID-19. *J Dig Endosc* 2020; 11: 3.
3. Ball P. The lightning–fast quest for COVID vaccines – and what it means for other diseases. *Nature* 2021; 589: 16–18.
4. US Food and Drug Administration. COVID-19 vaccines [Internet], 2022, https://www.fda.

gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/covid-19-vaccines (accessed 30 March 2022).

5. Loo KY, Letchumanan V, Ser HL, *et al.* COVID-19: insights into potential vaccines. *Microorganisms* 2021; 9: 1–19.
6. Kumar VM, Pandi-Perumal SR, Trakht I, *et al.* Strategy for COVID-19 vaccination in India: the country with the second highest population and number of cases. *Npj Vaccines* 2021;: 1–7.
7. Polack FP, Thomas SJ, Kitchin N, *et al.* Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *N Engl J Med* 2020; 383: 2603–2615.
8. Centre for Disease Control and Prevention. Pfizer-BioNTech COVID-19 vaccine reactions & adverse events. *CDC* [Internet], 2020, https://www.cdc.gov/vaccines/covid-19/info-by-product/pfizer/reactogenicity.html (accessed 30 March 2022).
9. Sofia S, Boccatonda A, Montanari M, *et al.* Thoracic ultrasound and SARS-COVID-19: a pictorial essay. *J Ultrasound* 2020; 23: 217–221.
10. Boccatonda A, Cocco G, Ianniello E, *et al.* One year of SARS-CoV-2 and lung ultrasound: what has been learned and future perspectives. *J Ultrasound* 2021; 24: 115–123.
11. Youn H and Hong KJ. Non-invasive molecular imaging of immune cell dynamics for vaccine research. *Clin Exp Vaccine Res* 2019; 8: 89–93.
12. Dialani V, James DF and Slanetz PJ. A practical approach to imaging the axilla. *Insights Imaging* 2015; 6: 217–229.
13. Shetty MK and Carpenter WS. Sonographic evaluation of isolated abnormal axillary lymph nodes identified on mammograms. *J Ultrasound Med* 2004; 23: 63–71.
14. Deurloo EE, Tanis PJ, Gilhuijs KGA, *et al.* Reduction in the number of sentinel lymph node procedures by preoperative ultrasonography of the axilla in breast cancer. *Eur J Cancer* 2003; 39: 1068–1073.
15. Scaranelo AM, Bukhanov K, Crystal P, *et al.* Granular cell tumour of the breast: MRI findings and review of the literature. *Br J Radiol* 2007; 80: 970–974.
16. Laor T, Collins MH, Emery KH, *et al.* MRI appearance of accessory breast tissue: a diagnostic consideration for an axillary mass in a peripubertal or pubertal girl. *AJR Am J Roentgenol* 2004; 183: 1779–1781.
17. Cocco G, Delli Pizzi A, Fabiani S, *et al.* Lymphadenopathy after the Anti-COVID-19 vaccine: multiparametric ultrasound findings. *Biology (Basel)* 2021; 10.
18. Studdiford J, Lamb K, Horvath K, *et al.* Development of unilateral cervical and supraclavicular lymphadenopathy after human papilloma virus vaccination. *Pharmacotherapy* 2008; 28: 1194–1197.
19. Shirone N, Shinkai T, Yamane T, *et al.* Axillary lymph node accumulation on FDG-PET/CT after influenza vaccination. *Ann Nucl Med* 2012; 26: 248–252.
20. And EC and for DP. COVID-19 vaccines [Internet], 2021, https://vaccination-info.eu/en/covid-19/covid-19-vaccines (accessed 3 April 2022).
21. Chapin-Bardales J, Gee J and Myers T. Reactogenicity following receipt of mRNA-based COVID-19 vaccines. *JAMA* 2021; 325: 2201–2202.
22. Brown A, Shah S, Dluzewski S, *et al.* Unilateral axillary adenopathy following COVID-19 vaccination: a multimodality pictorial illustration and review of current guidelines. *Clin Radiol* 2021; 76: 553–558.
23. Centers for Disease Control and Prevention (CDC). Moderna COVID-19 vaccine's reactions and adverse events. *CDC* [Internet], 2021, https://www.cdc.gov/vaccines/covid-19/info-by-product/moderna/reactogenicity.html (accessed 3 April 2022).
24. Agency EM. COVID-19 Vaccine Janssen. *European Medicines Agency* [Internet], 2021, https://www.ema.europa.eu/en/medicines/human/EPAR/covid-19-vaccine-janssen (accessed 30 March 2022).
25. GOV.UK. Regulatory approval of COVID-19 Vaccine AstraZeneca. *GOV.UK* [Internet]. Regulatory approval of COVID-19 Vaccine AstraZeneca, 2021, https://www.gov.uk/government/publications/regulatory-approval-of-covid-19-vaccine-astrazeneca (accessed 4 April 2022).
26. Park JY, Lee JY and Yi SY. Axillary lymphadenopathy on ultrasound after COVID-19 vaccination and its influencing factors: a single-center Study. *J Clin Med* 2022; 11: 238.
27. Granata V, Fusco R, Setola SV, *et al.* Lymphadenopathy after BNT162b2 Covid-19 vaccine: preliminary ultrasound findings. *Biology (Basel)* 2021; 10.
28. Mortazavi S. COVID-19 vaccination–associated axillary adenopathy: imaging findings and

follow-up recommendations in 23 women. *AJR Am J Roentgenol* 2021; 217: 857–858.

29. Hiller N, Goldberg SN, Cohen-Cymberknoh M, *et al*. Lymphadenopathy associated with the COVID-19 vaccine. *Cureus* 2021; 13.
30. Cocco G, Delli Pizzi A, Taraschi AL, *et al*. Atypical sites of lymphadenopathy after anti-COVID-19 vaccine: ultrasound features. *Med* 2022; 58: 197.
31. Washington T, Bryan R and Clemow C. Adenopathy following COVID-19 vaccination. *Radiology* 2021; 299: E280–E281.
32. Lehman CD, D'Alessandro HA, Mendoza DP, *et al*. Unilateral lymphadenopathy after COVID-19 vaccination: a practical management plan for radiologists across specialties. *J Am Coll Radiol* 2021; 18: 843–852.
33. Becker AS, Perez-Johnston R, Chikarmane SA, *et al*. Multidisciplinary recommendations regarding post-vaccine adenopathy and radiologic imaging: radiology scientific expert panel. *Radiology* 2021; 300: E323–E327.
34. Özütemiz C, Krystosek LA, Church AL, *et al*. Lymphadenopathy in COVID-19 vaccine recipients: diagnostic dilemma in oncologic patients. *Radiology* 2021; 300: E296–E300.
35. Nawwar AA, Searle J, Hagan I, *et al*. COVID-19 vaccination induced axillary nodal uptake on [18F]FDG PET/CT. *Eur J Nucl Med Mol Imaging* 2021; 48: 2655–2656.
36. Eifer M and Eshet Y. Imaging of COVID-19 vaccination at FDG PET/CT. *Radiology* 2021; 299: E248.
37. Hanneman K, Iwanochko RM and Thavendiranathan P. Evolution of lymphadenopathy at PET/MRI after COVID-19 vaccination. *Radiology* 2021; 299: E282.
38. Xu G and Lu Y. COVID-19 mRNA vaccination-induced lymphadenopathy mimics lymphoma progression on FDG PET/CT. *Clin Nucl Med* 2021; 46: 353–354.
39. McIntosh LJ, Bankier AA, Vijayaraghavan GR, *et al*. COVID-19 vaccination-related uptake on FDG PET/CT: an emerging dilemma and suggestions for management. *AJR Am J Roentgenol* 2021; 217: 975–983.
40. Avner M, Orevi M, Caplan N, *et al*. COVID-19 vaccine as a cause for unilateral lymphadenopathy detected by 18F-FDG PET/CT in a patient affected by melanoma. *Eur J Nucl Med Mol Imaging* 2021; 48: 2659–2660.
41. Moghimi S, Wilson D and Martineau P. FDG PET findings post-COVID vaccinations: signs of the times? *Clin Nucl Med* 2021; 46: 437–438.
42. Johnson BJ, van Abel KM, Ma DJ, *et al*. 18 F-FDG-avid axillary lymph nodes after COVID-19 vaccination. *J Nucl Med* 2021; 62: 1483–1484.
43. American College of Radiology. Breast imaging reporting & data system (BI-RADS®) [Internet]. *Reporting and Data Systems (RADS)*, https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/Bi-Rads (accessed 30 March 2022).
44. Mehta N, Sales RM, Babagbemi K, *et al*. Unilateral axillary Adenopathy in the setting of COVID-19 vaccine. *Clin Imaging* 2021; 75: 12.
45. Edmonds CE, Zuckerman SP and Conant EF. Management of unilateral axillary lymphadenopathy detected on breast MRI in the era of COVID-19 vaccination. *AJR Am J Roentgenol* 2021; 217: 831–834.
46. Grimm L, Destounis S, Dogan B, *et al*. *SBI recommendations for the management of axillary adenopathy in patients with recent COVID-19 vaccination*. Reston, VA: Society of Breast Imaging, 2021.
47. Schiaffino S, Pinker K, Magni V, *et al*. Axillary lymphadenopathy at the time of COVID-19 vaccination: ten recommendations from the European Society of Breast Imaging (EUSOBI). *Insights Imaging* 2021; 12: 119.
48. Bshesh K, Khan W, Vattoth AL, *et al*. Lymphadenopathy post-COVID-19 vaccination with increased FDG uptake may be falsely attributed to oncological disorders: a systematic review. *J Med Virol* 2022; 94: 1833–1845.
49. Moy L and Kim E. Follow-up of COVID-19 vaccine–related axillary lymphadenopathybefore 12 weeks is unnecessary. *Radiology*. Epub ahead of print 26 April 2022. DOI: 10.1148/radiol.220962.

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