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GENERAL REVIEW

Acute macular neuroretinopathy and COVID-19 vaccination: Case report and literature review

Neurorétinopathie maculaire aiguë et vaccination contre la COVID-19 : rapport de cas et revue de la littérature

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COVID-19; SARS-CoV-2; Vaccination; Acute macular neuroretinopathy; Oral contraceptives

Summary
Objective. — To review cases of acute macular neuroretinopathy (AMN) after COVID-19 vaccination and add a similar case to the literature.
Methods. — A thorough PubMed search was conducted, and data from studies describing AMN after COVID-19 vaccination were extracted, tabulated, pooled, and reviewed.
Results. — We present a case of AMN in a young woman 5 days after immunization with the BBIBP-CorV (Sinopharm) COVID-19 vaccine. Data from 21 cases were pooled and reviewed. The most frequent vaccines among the cases were recombinant ones (13/21), followed by mRNA-based

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Introduction

Mass COVID-19 vaccination programs are still underway to help further immunize at-risk populations and boost the limited/waning protection provided by previous vaccine doses; there are concerns regarding newer SARS-CoV-2 variants of unknown infectivity and virulence [1,2]. Among WHO-approved vaccines, the BBIBP-CorV COVID-19 vaccine (Sinopharm, China) is the most frequently injected in Iran [3,4]. It is an inactivated SARS-CoV-2 vaccine and has shown acceptable safety and efficacy [5]. However, some infrequent adverse events after immunization are not detected until vaccines are used widely enough for those events to occur and be documented — Mainly in the form of sporadic reports and observations.

Several cases of ocular adverse events after COVID-19 vaccination have been reported, including acute macular neuroretinopathy (AMN), ophthalmic vein thrombosis, corneal graft rejection, and uveitis [6]. AMN is a rare retinal disease of presumed vascular etiology, typically affecting young females. It presents through acute-onset unilateral/bilateral paracentral scotomata, often preceded by non-specific flu-like symptoms [7]. We reviewed and pooled the data from AMN cases following COVID-19 vaccination and added to the existing literature the case of a young female who developed flu-like symptoms after vaccination and noticed bilateral scotomas shortly afterward.

Methods

PubMed database was searched using a query consisting of the following terms: "acute macular neuroretinopathy", "AMN", "COVID-19", "SARS-CoV-2", "vaccination", "vaccine", and "immunization". The reference lists of the obtained records were manually searched for additional reports. Articles reporting one/multiple cases of AMN in individuals with recent vaccination against SARS-CoV-2 were included; no inclusion limitation regarding language, publication date, study design/method was set. Extracted data were patients’ demographic information, vaccine type (manufacturer), drug history, background
abnormality (tive visit, having – Sinopharm). was 2 later , books. phy , afferent (OU). reflectance ing An Case Results lesions condition, vaccination-to-symptoms time interval, presenting symptoms, findings on imaging studies, and outcome.

Results

Case presentation

An 18-year-old female with a complaint of reading problem was referred for retinal evaluation. Three weeks before our visit, she had taken her first dose of the BBIBP-CorV vaccine (Sinopharm). A day later, she experienced flu-like symptoms – including headache, fatigue, fever, and chills. Four days later, she noticed some spots of visual defects while reading books. Her medical history was unremarkable. She denied having contracted COVID-19.

Her clinical examination showed 20/20 visual acuity (OU). Upon slit lamp examination and fundus photography, hypopigmented perifoveal areas (OU) were detected (Fig. 1a and b). Ishihara test was normal, and no relative afferent pupillary defect was found. No anterior segment abnormality was detected. A Humphrey Visual Field 10-2 indicated paracentral scotomas in both eyes. Infrared reflectance (IR) imaging showed two perifoveal hyporeflective lesions (OD) – One superotemporal (wedge-shaped) and the other inferior and inferotemporal to the fovea (Fig. 1c, Fig. 2a) – And a diffuse perifoveal semi-circular hyporeflective lesion (OS) extending from the inferonasal axis to the superotemporal axis (Fig. 1d, Fig. 2d). Cross-sectional spectral-domain OCT (SD-OCT) showed OPL thickening, ONL thinning, and disruption of the ellipsoid zone in areas corresponding to the lesions (OU) (Fig. 2b and e). OCT angiography indicated no flow abnormality at superficial/deep retinal vasculature or choriocapillaris. Fluorescein angiography revealed no vascular pathology.

A diagnosis of AMN was made, and the patient was put on oral prednisolone 25 mg/day for ten days. On the follow-up visit, 14 days later, the visual field test indicated improvement of scotomas in both eyes; notably, the patient stated that her perceived visual disturbance had resolved. SD-OCT scan also showed partial improvement at the pathology sites (Fig. 2c and f).

Search results

In the literature, we found 18 articles that together reported 20 cases of AMN in people with recent COVID-19 vaccination. Patients’ demographic information, vaccine type (manufacturer), drug history, background condition(s),...
vaccination-to-symptoms interval, presenting symptoms, findings on imaging studies, and outcome were extracted and summarized in Table 1.

Discussion

AMN etiopathogenesis

The pathophysiology of AMN remains to be elucidated. Environmental triggers most frequently associated with AMN are non-specific flu-like symptoms, oral contraceptive use, epinephrine/ephedrine exposure, trauma, dehydration, and hypovolemia [7]. The retinal layers at which AMN-related structural pathologies are distributed (i.e., OPL, ONL, EZ) implies a vascular compromise and/or ischemic insult occurring at the deep capillary plexus (DCP) to be involved in AMN pathogenesis; each of the triggers above may induce such microvasculopathies in its own way [7].

AMN and COVID-19

Several cases of AMN have been reported during or after the COVID-19 infection course, with or without concurrent para-central acute middle maculopathy (PAMM) [8—10]. AMN can also surface as the first manifestation of COVID-19 infection [11]. The increased number of AMN cases identified in some ophthalmic care settings during the pandemic, compared to the pre-COVID era, raised suspicion of a causal link [12]. Viral illnesses have already been associated with AMN [7], and COVID-19 infection can impair the retinal microvasculature through mid- to long-term processes [13,14], further potentiating speculations on its association with AMN [15].

Pooled data from AMN cases after COVID-19 Vaccination

Rarely has AMN been reported after vaccination against pathogens other than SARS-CoV-2 (e.g., H1N1 and Neisseria meningitides) [16]. Amid the ongoing COVID-19 vaccination programs worldwide, reports of AMN after immunization have recently been described (Table 1).

Vaccine type

From the 21 cases described, 12 (57%) had taken the AZD1222 (AstraZeneca) and 1 (5%) the Ad26.COV2.S recombinant vaccines, 4 (19%) had received the BNT162b2 (Pfizer-BioNTech) and 2 (9%) the mRNA-1273 (Moderna) mRNA-platform vaccines, and 2 (9%; including our patient) had taken the BBIBP-CorV (Sinopharm) inactivated vaccine.

Demographic information and background conditions

Only one patient (5%) was male; 17 (81%) were young females aging between 18—33. Fourteen (67%) had concurrent/recent use of contraceptive medication (oral pills or vaginal rings). Thirteen (62%) had no remarkable past medical history; among the background conditions reported in cases were juvenile idiopathic arthritis [17], recurrent iritis [17], choroidal thickness (and a history of central serous chorioretinopathy) [18], type 2 diabetes mellitus [19], asthma [20], hypertension and end-stage renal disease [21], allergic rhinitis [22], myopia [19,22], and β thalassemia trait [23].

Time from vaccination to symptom onset

In most cases (90%; 19/21), the onset of symptoms was less than 8 days apart from the vaccination day, except for a 54-year-old male in whom symptoms manifested 21 days after immunization (case No. 10) [19] and a 42-year-old female whose scotoma was so peripheral that it was barely detectable — She first noticed it on day 45th after vaccination (case No 21) [24].

Imaging findings

The morphology of lesions showed variation among cases; bilateral lesions in our case showed both circumscribed, wedge-shaped, and diffuse, semi-circular patterns. The
Table 1  Identified cases of acute macular neuroretinopathy after COVID-19 vaccination in the literature.

| Case No./Author | Age/sex | Vaccine | Drug history/ background illness | Interval (days) | Presenting symptoms | Imaging features | Outcome |
|-----------------|---------|---------|----------------------------------|----------------|---------------------|-----------------|---------|
| #1 Fekri et al. | 18/F    | BBIBP-CorV [Sinopharm] | Unremarkable | 5 | Bilateral paracentral scotomas | IR: wedge-shaped (OD) and diffuse semi-circular (OS) perifoveal lesions | Objective resolution of visual defects and partial improvement of lesions on OCT and IR images at 2 weeks follow-up |
| #2 Book et al. [31] | 21/F    | AZD1222 [AstraZeneca] | OCP/— | 3 | Bilateral paracentral scotomas | IR: Bilateral confined paracentral lesions | NR |
| #3 Drüke et al. [17] | 23/F    | AZD1222 [AstraZeneca] | OCP, steroids/JIA & recurrent iritis | 1 | Bilateral paracentral scotomas | IR: Bilateral confined parafoveal lesions | Despite initial improvement, scotomas persisted with slow regression of lesion (in 15 weeks) |
| #4 Girbardt et al. [25] | 21/F    | AZD1222 [AstraZeneca] | — | 3 | Paracentral scotoma (OS) | OCT: OPL thickening — ONL thinning — EZ disruption | NR |
| Case No./Author | Age/sex | Vaccine | Drug history/background illness | Interval (days) | Presenting symptoms | Imaging features | Outcome |
|----------------|---------|---------|---------------------------------|----------------|---------------------|-----------------|---------|
| #5 Mambretti et al. [16] | 22/F | AZD1222 [AstraZeneca] | OCP/— | 2 | Scotoma (OD) | IR: Tear drop-shaped perifoveal lesions OCT: hyperreflectivity of OPL and ONL — EZ disruption | NR |
| #6 Mambretti et al. [16] | 28/F | AZD1222 [AstraZeneca] | OCP/— | 2 | Paracentral scotoma (OD) | IR: wedge-shaped lesion in papillo-macular bundle OCT: hyperreflectivity of OPL and ONL — EZ attenuation | NR |
| #7 Pichi et al. [18] | NR | BBIBP-CorV [Sinopharm] | CSCR (OU)—chronic serous PED (OS)—Choroidal thickness | 5 | Acute vision loss (OS) | OCT: hyperreflectivity of OPL, HFL, and ONL — EZ attenuation | BCVA improvement & resolution of OCT findings (at 2 months follow-up) |
| #8/Valenzuela et al. [26] | 20/F | BNT162b2 [Pfizer-BioNTech] | CVR/— | 2 | Photopsia and bilateral scotomas | OCT: parafoveal hyperreflective foci at ONL—EZ granularity | Complete resolution of scotomas (at 1 week follow-up) NR |
| #9 Bahler et al. [29] | 27/F | AZD1222 [AstraZeneca] | OCP/— | 2 | Paracentral scotoma (OS) | OCT: Teardrop-shaped macular lesion (en face view)/hyperreflectivity of OPL and ONL — EZ disruption (cross-sectional view) IR: 2 parafoveal oval hyperreflective lesions (OS) | NR |
| #10 Chen et al. [32] | 21/F | BNT162b2 [Pfizer-BioNTech] | OCP/— | 3 | Paracentral scotoma (OS) | OCT: focal areas of paracentral OPL and ONL hyperreflectivity — EZ disruption | Gradual reduction of scotoma intensity over 10 weeks |
| Case No./Author  | Age/sex | Vaccine            | Drug history/ background illness       | Interval (days) | Presenting symptoms          | Imaging features                              | Outcome                                                                 |
|-----------------|---------|--------------------|----------------------------------------|----------------|-----------------------------|-----------------------------------------------|-------------------------------------------------------------------------|
| #11 Diafas et al. [19] | 54/M    | BNT162b2 [Pfizer-BioNTech] | NR/T2DM, low myopia                      | 21             | Photopsia and small scotoma (OS) | OCT: OPL hyperreflective band — EZ disruption | Remained symptomatic at 2 months follow-up                               |
| #12 Franchi et al. [20] | 19/F    | AZD1222 [AstraZeneca]     | OCP (DC 2 months before presentation)/asthma | 1              | fortification (OS)          | NIR: multiple wedge-shaped hyporeflective lesions (OU) | Persisting visual symptoms and photoreceptor layer derangement, despite resolution of hyperreflective bands, at 8 weeks follow-up |
| #13 Franchi et al. [20] | 31/F    | AZD1222 [AstraZeneca]     | OCP/—                                   | 2              | fortification and paracentral scotoma (OD) | OCT: parafoveal OPL & ONL hyperreflective bands — EZ disruption (OU) | Persisting visual symptoms and photoreceptor layer derangement, despite resolution of hyperreflective bands, at 15 weeks follow-up |
| #14 Gabrielle et al. [33] | 25/F    | AZD1222 [AstraZeneca]     | OCP/—                                   | 1              | Bilateral paracentral scotomas | OCT: OPL & ONL hyperreflective bands — EZ disruption (OU) | NR                                                                      |
| Case No./Author | Age/sex | Vaccine        | Drug history/ background illness | Interval (days) | Presenting symptoms | Imaging features                                                                 | Outcome                                                                 |
|----------------|---------|----------------|---------------------------------|----------------|---------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| #15 Michel et al. [34] | 21/F     | AZD1222 [AstraZeneca] | OCP/—                            | 2              | 4 central scotomas (OS) | OCT: OPL hyperreflectivity and thickening — ONL thinning — Disruption of EZ | Improvement of symptoms, visual field, and OCT biomarkers at 6 weeks follow-up |
| #16 Ishibashi et al. [21] | 33/F     | BNT162b2 [Pfizer-BioNTech] | NR/HTN, Alport syndrome, ESRD | 8              | Visual field defect (OS) | OCT: hyperreflective foci of OPL and ONL — EZ disruption | NR                                                                       |
| #17 Patel et al. [35] | 26/F     | Ad26.COV2.S [Janssen] | OCP/—                            | 2              | Bilateral paracentral scotomas | OCTA: signal absence at DCP in the corresponding area | NR                                                                       |
| #18 Priluck et al. [22] | 20/F     | mRNA-1273 [Moderna] | OCP, fluticasone, loratadine/allergic rhinitis, myopia | 8              | Bilateral central scotomas | NIR: wedge-shaped parafoveal lesions (OS) | Progressive subjective improvement of scotomas w/o complete resolution |
| Case No./Author | Age/sex | Vaccine | Drug history/background illness | Interval (days) | Presenting symptoms | Imaging features | Outcome |
|----------------|---------|---------|--------------------------------|----------------|---------------------|-----------------|---------|
| #19 Sanjay et al. [23] | 25/F | AZD1222 [AstraZeneca] | /- β thalassemia trait | 3 | Blurry vision and Shadow (OD) – one week later, a new scotoma was noticed | OCT: EZ disruption at corresponding lesion locations | NIR: normal | Resolution of AMN (OD) and development of Similar symptoms and findings (OS) a month later |
| #20 Zaheer et al. [36] | 22/F | AZD1222 [AstraZeneca] mRNA-1273 [Moderna] | NA | <7 | NA | OCT: hyperreflective area at OPL and ONL | NA | OCT: subtle changes of the ONL and photoreceptor layers | SCOTOMA was still present but had diminished in size (at 1-month follow-up) |
| #21 Jalink et al. [24] | 42/F | mRNA-1273 [Moderna] | OCP/- | NA | Barely noticeable scotoma, temporal to the center (OS) | OCT: subtle changes of the ONL and photoreceptor layers | NA | |

AMN: acute macular neuroretinopathy; BCVA: best-corrected visual acuity; CSCR: central serous chorioretinopathy; CVR: contraceptive vaginal ring; DC: discontinued; DCP: deep capillary plexus; ELM: external limiting membrane; ESRD: end-stage renal disease; EZ: ellipsoid zone; F: female; HFL: Henle fiber layer; HTN: hypertension; IR: infrared reflectance; IZ: interdigitation zone; JIA: juvenile idiopathic arthritis; M: male; NA: not available; NIR: near-infrared reflectance; NR: not reported; OCP: oral contraceptive pills; OCT: optical coherence tomography; OCTA: optical coherence tomography angiography; OD: oculus dexter; ONL: outer nuclear layer; OPL: outer plexiform layer; OS: oculus sinister; OU: oculus uterque; PED: pigment epithelial detachment; T2DM: type 2 diabetes mellitus.

a The exact time of symptom onset was unclear, but the time from her last vaccine dose to realizing her visual field defect was ~ 45 days; her scotoma was hard to perceive and would be noticed only when she closed her right eye.
most frequent lesion morphology was confined wedge-/oval-shaped; a diffuse macular lesion was rarely documented (cases 1 and 7 [18]).

In all cases, SD-OCT was able to detect abnormal structural findings — in some instances, even in the fellow eyes, from which no subjective visual defect was perceived [20,25]. SD-OCT, in conjunction with near-infrared reflectance (NIR), is suggested as the modality of choice in the detection of AMN-related abnormalities not spotted upon clinical examination and color fundus photography (7).

Outcome

Only twelve reports included follow-up data. Follow-up periods were quite heterogeneous, and so were the outcomes and the time it took for scotomas to resolve. While scotomas became subjectively unnoticeable within 4 weeks in some cases (e.g., cases No. 1 and 8 [26]), some patients were still symptomatic at 15 weeks follow-up (e.g., cases No. 3 [17], 13 [20]) — these were the two ends of the spectrum.

Causality assessment and possible pathomechanisms

The Naranjo probability scale may prove helpful in evaluating adverse drug reactions more objectively [27]. Based on ten criteria, a probability score is assigned (≥ 9, definite; 5–8, probable; 1–4, possible, and ≤ 0, doubtful). Our case was assigned a score of 7, based on the criteria below, and thus, deemed a "probable" vaccine-associated event:

- "Are there previous conclusive reports on this reaction? - Yes (+1);
- "Did the adverse event appear after the suspected drug was administered? - Yes (+2);
- "Did the adverse event improve when the drug was discontinued, or a specific antagonist was administered? - Yes (+1); the patient refrained from the second dose vaccination and has experienced no further retinal ischemic event;
- "Are there alternative causes that could on their own have caused the reaction? - No (+2);
- "Was the adverse event confirmed by any objective evidence? - Yes (+1).

Naranjo scores of all cases reviewed in Table 1 are interpreted as either "possible" or "probable" and cannot exceed 8 because some algorithm criteria are not applicable in this context. For instance, "dose adjustment", "toxic serum concentrations", "past exposure to similar drugs", and "placebo administration" are not relevant concepts in the case of COVID-19 vaccines administered routinely.

However, hormonal contraception bears an established risk of microvascular endothelial dysfunction [28], and a positive history of OCP use, present in 14/21 (67%) of the reviewed cases, may argue against pointing the finger at vaccines with certainty [16]. On the other hand, some explanatory mechanisms are proposed regarding how vaccines may be associated with microvasculopathic events, as discussed below.

Böhler et al. suspected vaccine-induced thrombotic thrombocytopenia (VITT) in their patient [29]. VITT has recently been described as primarily associated with the AZD1222 adenoviral vector-based vaccine. Like heparin-induced thrombocytopenia, it involves autoantibodies that activate platelets and induce thrombotic events in arterial or venous circulations, ultimately resulting in consumptive coagulopathy [30]. However, the clinical picture of VITT is discordant with AMN; it often occurs around 14 days after inoculation (the time needed for seroconversion) and most often involves simultaneous large vessel thromboses at different sites (e.g., cerebral venous sinus thrombosis, deep vein thrombosis, and pulmonary embolism) [30]. Böhler et al. found no serological evidence of VITT [29]. Other more plausible mechanisms include induction of an inflammatory milieu by the adenoviral vector, giving rise to arterial endothelial vasomotor dysfunction and/or worsening of an already-thrombophilic status (because of hormonal contraceptive use) [16].

Conclusion

Vaccination remains our most effective means of protection against emerging SARS-CoV-2 variants, and one would expect further doses to be advised in the near future. Thus, the number of reported AMN cases in the temporal proximity of vaccination may continue to grow. Regardless of a causative association, it is necessary to pay attention to COVID-19 vaccine and OCP use history in patients with sudden-onset visual symptoms, such as scotomas. In many instances, clinical examination and fundus color photography may be of lower diagnostic yield than SD-OCT and NIR in diagnosing AMN.

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Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Andrews N, Stowe J, Kirsebom F, Toffa S, Rickeard T, Gallagher E, et al. COVID-19 vaccine effectiveness against the Omicron (B.1.1.529) variant. N Engl J Me 2022;386:1532–46.
[2] Magen O, Waxman JG, Makov-Assif M, Vered R, Dicker D, Hernán MA, et al. Fourth dose of BNT162b2 mRNA COVID-19 vaccine in a nationwide setting. N Engl J Med 2022;386:1603–14.
[3] Azadmanesh K. Iran hopes to defeat COVID with home-grown crop of vaccines [Internet]. 2021 [cited 2022 Jul 17]. Available from: https://www.nature.com/articles/d41586-021-02216-z.
[4] Hosseinzadeh A, Sahab-Negah S, Nili S, Aliyari R, Goli S, Feriedouni M, et al. COVID-19 cases, hospitalizations and deaths
after vaccination: a cohort event monitoring study, Islamic Republic of Iran. Bull World Health Organ 2022;100:474–83.

[5] Al Kaabi N, Zhang Y, Xia S, Yang Y, Al Qahtani MM, Abdurrazzaq N, et al. Effect of 2 inactivated SARS-CoV-2 vaccines on symptomatic COVID-19 infection in adults: a randomized clinical trial. JAMA 2021;326:35.

[6] Ng XL, Betzler BK, Testi I, Ho SL, Tien M, Ngo WK, et al. Occlusive adverse events after COVID-19 vaccination. Ocul Immunol Inflamm 2021;29:1216–24.

[7] Bhavasar KV, Lin S, Rahimy E, Joseph A, Freund KB, Sarraf D, et al. Acute macular neuroretinopathy: a comprehensive review of the literature. Surv Ophthalmol 2016;61:538–65.

[8] Virgo J, Mohamed M. Paracentral acute middle maculopathy and acute macular neuroretinopathy following SARS-CoV-2 infection. Eye (Lond) 2020;34:2352–3.

[9] Gascon P, Briantais A, Bertrand E, Ramtohul P, Comet A, Beylerian M, et al. COVID-19-Associated retinopathy: a case report. Ocul Immunol Inflamm 2020;28:1293–7.

[10] Zamani G, Ataei Azimi S, Aminizadeh M, Shams Abadi E, Kamandi M, Mortazi H, et al. Acute macular neuroretinopathy in a patient with acute myeloid leukemia and deceased by COVID-19: a case report. J Ophthalmic Inflamm Infect 2021;10:39.

[11] Preti RC, Zacharias LC, Cunha LP, Monteiro MLR. Acute macular neuroretinopathy as the presenting manifestation of COVID-19 infection. Retin Cases Brief Rep 2022;16:12–5.

[12] Ahmed W, Surí A, Ahmed A. COVID-19 and acute macular neuroretinopathy – An underlying association? Ann Med Surg 2022;78:103847.

[13] Wang S, Wang J, Hu J, Wang N. Retinal microvascular impairment in COVID-19 patients: a meta-analysis. Immun Inflamm Dis 2022;10:e619.

[14] Nourinia R, Ghasempour M, Ahmadieh H, Abtahi SH. Branch retinal vein occlusion after COVID-19. J Fr Ophtalmol 2021;44:e441–3.

[15] Capuano V, Forte P, Sacconi R, Miere A, Mehanna CJ, Barone C, et al. Acute macular neuroretinopathy as the first stage of SARS-CoV-2 infection. Eur J Ophtalmol 2022;11:120672122010906.

[16] Mambretti M, Huemer J, Torregrossa G, Ullrich M, Findl O, Casalino G. Acute Macular Neuroretinopathy following Coronavirus Disease 2019 vaccination. Ocul Immunol Inflamm 2021;29:730–3.

[17] Druke D, Pleyer U, Hoerauf H, Feltgen N, Bemme S. Acute macular neuroretinopathy (AMN) following COVID-19 vaccination. Am J Ophthalmol Case Rep 2021;24:101207.

[18] Pichi F, Aljneibi S, Neri P, Hay S, Dackiw C, Ghazi NG. Association of ocular adverse events with inactivated COVID-19 vaccination in patients in Abu Dhabi. JAMA Ophthalmol 2021;139:1131–5.

[19] Diafas A, Ghadirli N, Beare N, Madhusudhan S, Pearce I, Tan SZ. Comment on: paracentral acute middle maculopathy and acute macular neuroretinopathy following SARS-CoV-2 infection. Eye 2022;36:1507–9.

[20] Franchi A, Rauchegger T, Palme C, Frede K, Haas G, Blatios G, et al. Two cases of acute macular neuroretinopathy associated with the adenovirus-based COVID-19 vaccine Vazzxvitra (Astrazeneca). Ocul Immunol Inflamm 2022;20:1–6.

[21] Ishibashi K, Yatsuka H, Haruta M, Kimoto K, Yoshiha S, Kubota T. Branch retinal artery occlusions, paracentral acute middle maculopathy and acute macular neuroretinopathy after COVID-19 vaccinations. OPHT 2022;16:987–92.

[22] Priluck AZ, Arevalo JF, Pandit RR. Ischemic retinal events after COVID-19 vaccination. Am J Ophthalmol Case Rep 2022;26:101540.

[23] Sanjay S, Gadde SGK, Kumar Yadav N, Kawali A, Gupta A, Shetty R, et al. Bilateral sequential acute macular neuroretinopathy in an Asian Indian female with β Thalassemia trait following (Corona Virus Disease) COVID-19 vaccination and probable recent COVID infection- multimodal imaging study. Ocul Immunol Inflamm 2022;20:1–6.

[24] Jalink MB, Bronkhorst IHG. A sudden rise of patients with acute macular neuroretinopathy during the COVID-19 pandemic. Case Rep Ophthalmol 2022;13:96–103.

[25] Giribardi C, Busch C, Al-Sheikh M, Gunzinger JA, Invernizzi A, Xhepa A, et al. Retinal vascular events after mRNA and adenoviral-vectorized COVID-19 vaccines – A case series. Vaccines (Basel) 2021;9:1349.

[26] Valenzuela DA, Groth S, Taubenslag KJ, Gangaputra S. Acute macular neuroretinopathy following Pfizer-BioNTech COVID-19 vaccination. Am J Ophthalmol Case Rep 2021;24:101200.

[27] Naranjo CA, Busts O, Sellers EM, Sandoz P, Ruiz I, Roberts EA, et al. A method for estimating the probability of adverse drug reactions. Clin Pharmacol Ther 1981;30:239–45.

[28] Williams JS, MacDonald MJ. Influence of hormonal contraceptives on peripheral vascular function and structure in premenopausal females: a review. Am J Physiol Heart Circ Physiol 2021:320:H77–89.

[29] Behler AD, Strom ME, Sandvig KU, Moe MC, Jørstad ØK. Acute macular neuroretinopathy following COVID-19 vaccination. Eye 2022;36:644–5.

[30] Klokk FA, Pai M, Huisman MV, Makris M. Vaccine-induced immune thrombocytopenia. Lancet Haematol 2022:9:e73–80.

[31] Book BAJ, Schmidt B, Foerster AMH. Bilateral acute macular neuroretinopathy after vaccination against SARS-CoV-2. JAMA Ophthalmol 2021;139:e212471.

[32] Chen S, Hodge C. Comment on: acute macular neuroretinopathy following COVID-19 vaccination. Eye 2022;36:1513–4.

[33] Gabrielle PH, Baudin F, Ben Ghezala I, Meillon C, Bron AM, Arnould L, et al. Bilateral acute macular neuroretinopathy in a young woman after the first dose of Oxford-AstraZeneca COVID-19 vaccine. Am J Ophthalmol Case Rep 2022;25:101281.

[34] Michel T, Stolowy N, Gascon P, Dupessay F, Comet A, Attia R, et al. Acute macular neuroretinopathy after COVID-19 vaccine. J Fr Ophtalmol 2022;S0181-5512:00162.

[35] Patel SN, Yonekawa Y. Acute macular neuroretinopathy after SARS-CoV-2 vaccination. Retin Cases Brief Rep 2022;16:5–8.

[36] Zaeheer, N, Renju MP, Chavan R. Acute macular neuroretinopathy after COVID-19 vaccination. Retin Cases Brief Rep 2022;16:9–11.