Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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A retrospective analysis of social media posts pertaining to COVID-19 vaccination side effects

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ABSTRACT

Objectives: With an uprising influence of social media platforms like Twitter and Instagram a multitude of worldwide accessible information is available. Since the beginning of COVID-19 pandemic the exchange of medical information about several topics related to this infectious disease and its vaccination has increased rapidly. The purpose of this investigation was to assess the content associated with COVID-19 vaccination and its side effects and evaluate its educational quality.
Methods: We conducted this retrospective study to investigate 600 Twitter and Instagram posts by #covidvaccinesideeffects due to number of 'likes', comments, type of post, language, its purpose and source. In addition, posts were evaluated due to educational quality by three examiners of different educational levels.
Results: The majority of posts showed 0 to 50 "likes" and 0 to 5 comments in English language. A comparison between Twitter and Instagram by the influence of application showed significant differences in number of posts and "likes" or comments ($p < 0.05$). The major post type were texts for Twitter (251; 83.7%) and videos for Instagram (104; 34.7%). While a majority of posts by #covidvaccinesideeffects report about the occurrence of side effects, the majority of them were mild and general COVID-19 vaccination feedback during the first 4 months was positive. But, only 3 to 7% were rated by "excellent" educational and validatable content. Interrater reliability between all three examiners presented a high concordance with 89% ($p = 0.001$).
Conclusions: This study presents an analysis of quantity and quality of social media content according to COVID-19 vaccinations and its side effects. It supports the deduction that most of the content on Twitter and Instagram is shared by patients and unclear sources and thus is limited informative. Nevertheless, influence of social media on medical information especially during COVID-19 pandemic is increasing and practitioners have to face its effect on their patients.

1. Introduction:

Since December 2019 severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) affects most of human population as a worldwide pandemic [1]. SARS-CoV-2 is the third known coronavirus which is highly pathogenic for humans. Perpetuation is likely caused by a very transmissible virus with an extended tissue tropism [2]. Three large outbreaks of coronaviruses (CoVs) have been detected over the last two decades. These were severe acute respiratory syndrome (SARS), Middle Eastern respiratory syndrome (MERS) and currently SARS-CoV-2. The origin detected by the first patient registered on December 1, 2019 was traced back to a seafood market in Wuhan City, Hubei Province, China [3]. In March 2020 the World Health Organization declared SARS-CoV-2 as a pandemic. Until today, over 149 million people have been infected by the virus, over 3 million people died and more than 235 countries have been affected so far [2].

Until today, World Health Organization reports investigations of more than 250 different SARS-CoV-2 vaccines. More than 80 vaccines are investigated in clinical trials and another 180 in preclinical trials [4,5]. Since December 2020 (BNT162b2) and January 2021 (mRNA-1273) two mRNA vaccines against SARS-CoV-2 have been approved for the European Union (EU) [6,7]. Also, in January 2021 (AZD1222) and in March 2021 (Ad26.COV2-S) two further vector vaccines were approved by the European Medicines Agency (EMA) [8,9]. The approval of Russian Sputnik V vector vaccine is

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currently part of a rolling-review process for the European Union [9]. The majority of these vaccines have been first approved by Food and Drug Administration (FDA) for the United States (US) followed by EMA for EU and several other countries worldwide followed [7,8].

So far it could be shown, that vaccinated individuals are protected against symptomatic COVID-19 infections and severe progressions for at least 3 months [7]. In particular elderly people are protected who are exceedingly endangered. Unfortunately, safety data and efficacy are insufficient in accordance with immune compromised, pregnant and pediatric patients yet. First clinical studies due to approved mRNA vaccines report an efficacy of avoidance of severe disease of more than 90% [7,8].

Nevertheless, a general vaccine hesitancy is spread in many countries. A fairly new and still partially known pandemic, a rapid vaccine development, a short follow up of clinical studies and vaccine side effects make people visualize more risks than benefits [10,11].

Besides that, Internet has taken an important part in our life during the last decades and provides an indispensable source of information for about two-thirds of world's population, especially during a pandemic [12]. In context with COVID-19 related topics, many patients use the Internet as a presumably reliable source of information [13]. Consequently, patients are influenced and it affects their attitudes towards practitioners and healthcare professionals [13]. The variety of information offers potential benefits by easily accessible health information on the Internet and its social media platforms, but valuable information is accompanied with masses of unfiltered and not validated data and misinformation. The spread of incorrect content through social media sources is an important and challenging issue especially for healthcare related topics [14]. While platforms like Twitter and Instagram filter for sexual, racial and content of violence, anyone can share any medical or healthcare related information on these platforms without validation of experts or professionals [15].

Twitter and Instagram are some of the most popular social media platforms, as free available text, photograph and video sharing applications [16]. Since their establishment in 2010, its huge user base is rapidly increasing and the platform is currently one of the most visited web sites in the world and previous scientific studies have been conducted on these platforms [16]. Today, Twitter and Instagram have more than one billion users each, who spend more than 5 min on average on the application and more than 100 million texts, photographs or videos are shared every day [15,17]. Both platforms aim for short posts including text or pictures so that a comparison is nearby. A similar number of posts by #covidvaccinesideeffects, the most common hashtag according this topic could be found for both applications. Besides that, a majority of Twitter and Instagram posts were for public available while e.g. several Facebook posts were blocked as private content.

Besides all types of accounts and topics, Twitter and Instagram host several accounts affecting the field of medicine. The majority of posts are shared by healthcare professionals, clinics, and patients with a variety of videos or photographs covering personal experience, case reports or treatment suggestions [15]. However, information is predominantly provided without any type of validation or professional review and accuracy and reliability cannot be guaranteed [18].

Several investigations were conducted analyzing the relationship between social media and COVID-19 pandemic [13]. No study thus far has investigated the information about SARS-CoV-2 vaccination and its side effects on Twitter and Instagram. Thus, we conducted this study to evaluate the content on Twitter and Instagram by #covidvaccinesideeffects posts and to review their quality.

2. Materials and methods:

2.1. Patients and data collection

Public social media posts on Twitter (www.twitter.com) and Instagram (www.instagram.com) with the hashtag "#covidvaccinesideeffects" were retrospectively reviewed, compared between the two platforms and analyzed manually by three investigators between January and April 2021. The hashtag has been chosen based on the most common findings on Twitter and Instagram in accordance with COVID-19 vaccination and its side effects (Fig. 1). At the beginning of our study in January 2021 this hashtag was the only one which combined posts regarding COVID-19, vaccination and its side effects. Thus, it was the only one commonly used at this time, including all aspects and its analysis was nearby. The study was divided into four parts.

In part one a total number of 300 Twitter and 300 Instagram posts with #covidvaccinesideeffects was recorded and analyzed. The number of 'likes' and comments for the selected posts was categorized, according to the gender, the language it was posted in, country of origin, type of posts (text, photo single or multiple, video), its purpose (patient experience, news, academical, advertisement, unknown) and its source (patients, news, other, healthcare professionals, unknown, clinic, company). A total of 600 posts have been assessed, variables were 'likes', comments, gender, language, origin, type, purpose and source. Data are presented in total (n) and percentage (Table 1).

In part two we assessed the influence by comparing 300 Twitter and 300 Instagram by the number of 'likes' and comments. The *chi-squared* test was applied to assess a correlation between type of social media platform (Twitter vs. Instagram) and number of 'likes' and comments. A total of 600 posts have been analyzed by cross-tabulations (Table 2).

In part three we analyzed 300 Twitter and 300 Instagram posts of #covidvaccinesideeffects by side effect (yes, no, not named), type of side effect (pain, swelling, fever, headache, fatigue, allergic reaction, other, multiple, not applied) time after vaccination (hours, days, weeks, unknown, not applied), count of vaccination (first, second, third, unknown, not applied), type of vaccine (Biontech/Pfizer, Moderna, Astra Zeneca, other, unknown, not applied) and patient feedback (positive, negative, neutral, unknown). Patients feedback was analyzed with regard to the vaccination itself (vaccine accessibility, type of vaccine, information about vaccine, vaccination process) and the side effects (occurrence, period of side effect, information about side effect, comparability with other vaccination) they experienced. Not every post reported about all feedback aspects, so that only an overall feedback could be assessed. Following the validated protocol of Kim et al., feedback analysis was performed using Text Analytics API in Microsoft Azure Cognitive Services (https://azure.microsoft.com/services/cognitive-services/text-analytics/) [19]. For each post, it assessed a score between 0, which represents being most negative, and 1, which represents being most positive feedback [19]. A score of 0.5 was defined as neutral and if analysis couldn't be performed it was defined as unknown feedback. 600 posts have been assessed, variables were presence of side effect, type of side effect, vaccination time, vaccination count, vaccine and feedback. Data are presented in total (n) and percentage (Table 3).

In addition, posts with most 'likes' (>100) and comments ($\geq$10) were analyzed further for their content in accordance with purpose, source, side effects, type of side effects and patient feedback. 66 posts have been assessed and data are presented in total (n) and percentage (Table 4).

In part four we retrospectively analyzed the 100 Twitter and 100 Instagram #covidvaccinesideeffects posts between January

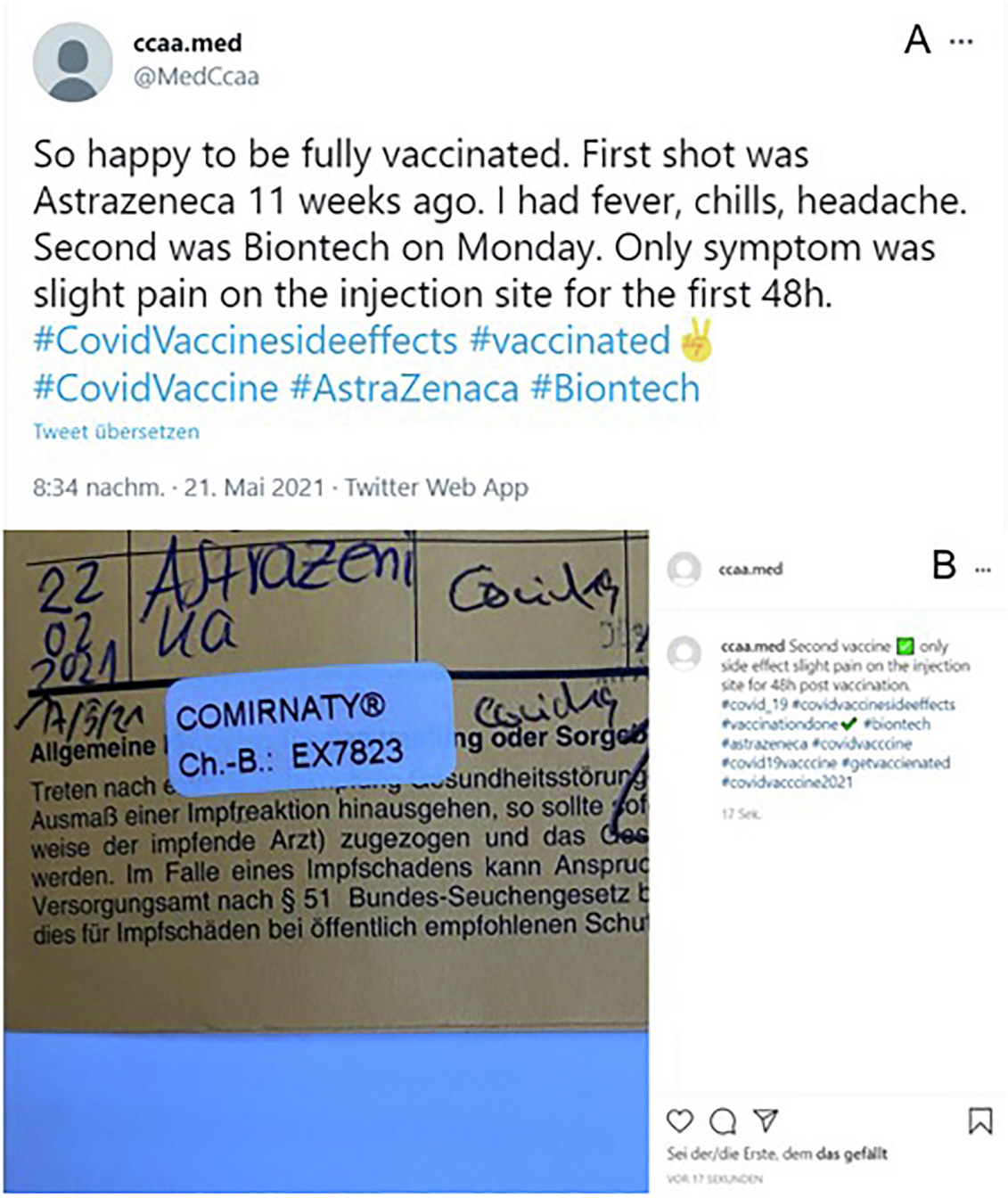

Fig. 1. Two exemplary posts about COVID19 vaccination and its side effects shared on Twitter (A) and Instagram (B) by #covidvaccinesideeffects.

and April 2021. Posts were randomly picked from the pool of 600 posts of part one to three and investigated by the same criteria. In part four the 200 posts were evaluated due to their educational quality by three examiners of three different educational levels. A medical student, a resident medical doctor and a senior consultant medical doctor have rated the posts in three categories (poor, moderate and excellent) following the protocol of Hegarty et al. [20].

A poor quality post is defined by false or misinformation, information is not useful for other users or is contrary toward scientific data or studies. A moderate post contains incomplete information, is only partly useful for other users and is debatable with scientific data. A post of excellent quality contains sufficient and substantial information, is useful for other users or even patients and coincides with the majority of scientific knowledge [20]. For evaluation of educational quality an interrater reliability analysis was performed by kappa statistic. Measurement of the extent to which raters assign the same score to the same variable is called interrater reliability. While there have been a variety of methods to measure interrater reliability, by this established method it was measured as percent agreement, calculated as the number of agreement scores divided by the total number of scores [21].

Posts that were duplicates, or not related to COVID-19 vaccination and its side effects were excluded from the study with the consensus of the authors. All recorded URLs of each post were analyzed within 4 weeks and deleted, or inaccessible posts removed.

Due to public data and the pure retrospective nature of this investigation, local ethics committee exempts this study from a specific ethics vote. Patients' data were treated confidentially and

Table 1
Analysis of 300 Twitter and 300 Instagram posts of #covidvaccinesideeffects according to 'likes' and comments, type, purpose and source. Data presented as n and percentage (%).

		Twitter		Instagram	
		Total	Percentage (%)	Total	Percentage (%)
Number of 'likes'					
	0–50	264	88	230	76.7
	51–100	5	1.7	35	11.7
	>100	31	10.3	35	11.7
Number of comments					
	0–5	261	87	196	65.3
	6–10	9	3	46	15.3
	>10	30	10	58	19.3
Type					
	Photo single	22	7.3	92	30.7
	Photo multiple	8	2.7	52	17.3
	Video	19	6.3	104	34.7
	Text	251	83.7	52	17.3
Purpose					
	Patient experience	192	64	205	68.3
	News	89	29.7	63	21
	Academic	16	5.3	23	7.7
	Advertisement	0	0	7	2.3
	Unknown	3	1	2	0.7
Source					
	Patient	181	60.3	205	68.3
	Professional	19	6.3	11	3.7
	News	60	20	35	11.7
	Company	0	0	3	1
	Clinic	1	0.3	3	1
	Other	33	11	37	12.3
	Unknown	6	2	6	2

Table 2
Analysis of 300 Twitter and 300 Instagram posts of #covidvaccinesideeffects according to 'likes' and comments by chi-squared test. *P* values $p < 0.05$ were considered significant.

	'likes'			Comments		
	0–50	51–100	>100	0–5	6–10	>10
Twitter	264	5	31	261	9	30
Instagram	230	35	35	195	46	58
Total	494	40	66	456	55	88
Person-Chi-Square	$\chi^2 = 25.083$		$P = 0.001$	$\chi^2 = 44.353$		$P = 0.001$

anonymized when extracted from the files. The study was conducted in accordance with the ethical principles of the declaration of Helsinki and its further amendments.

2.2. Statistical analysis

All data were assessed using SPSS (Superior Performance Software System), version 22.0 (IBM, Germany). Descriptive statistics were calculated for quantitative variables ('likes' and comments) and Kolmogorov-Smirnov and Shapiro-Wilk proofed Normal Distribution. Categorical variables were presented in total numbers (n) and percentages of all recorded posts. For comparison between Twitter and Instagram by 'likes' and comments *chi-squared* test was applied and for evaluation of educational quality an interrater reliability analysis by kappa statistic was performed. *P* values $p < 0.05$ were considered significant.

3. Results:

Our study consisted of 600 posts by the hashtag #covidvaccinesideeffects on Twitter and Instagram analyzed between January and April 2021 by a medical student, a resident medical doctor and a senior consultant medical doctor.

3.1. Analysis of 600 #covidvaccinesideeffects posts on Twitter and Instagram

In a period of four month between January and April 2021 a total number of 300 Twitter and 300 Instagram posts by #covidvaccinesideeffects could be analyzed. Twitter posts were distributed as follows. 141 (47%) were posted by females, 102 (34%) by males and for 57 (19%) gender was unknown. The majority of Twitter posts were in English (285; 95%), followed by German (4; 1.3%), French (2; 0.7%), Hindi posts (2; 0.7%) and other languages of 1 (0.3%) post each, respectively. The country of origin was mainly the US (164; 54.7%), followed by 62 (20.7%) unknown posts, 22 (7.3%) from UK, 15 (5%) from India, 10 (3.3%) from Canada, 6 (2%) from Germany, 4 (1.3%) from Australia, 2 (0.7%) posts each respectively from France, South Africa and Norway, and furthermore 1 (0.3%) post each respectively from other countries. The analysis of Twitter post type showed that the majority of posts were texts (251; 83.7%), followed by single photographs (22; 7.3%), videos (19; 6.3%) and multiple photographs (8; 2.7%). The Twitter post purpose assessed a majority of patient experiences (192; 64%), followed by 89 (29.7%) posts of news, 16 (5.3%) with academic purpose and 3 (1%) posts with an unknown purpose. The analysis of source showed 181 (60.3%) Twitter posts by patients, followed by 60 (20%) posts from news sources, 33 (11%) of other sources, 19 (6.3%) by healthcare professionals, 6 (2%) unknown sources and last 1 (0.3%) post from a clinic (Table 1).

Table 3
Analysis of vaccination side effects post by #covidvaccinesideeffects according to side effects, type of side effect, time after vaccination, vaccination count, vaccine and feedback. Data presented as n and percentage (%).

		Twitter	Instagram
Reported side effects			
	Yes	156 (52)	162 (54)
	No	42 (14)	41 (13.7)
	Not named	102 (34)	97 (32.3)
Type of side effect described			
	Pain	30 (10)	43 (14.3)
	Swelling	2 (0.7)	1 (0.3)
	Headache	3 (1)	1 (0.3)
	Fatigue	10 (3.3)	4 (1.3)
	Allergical reaction	6 (2)	3 (1)
	Multiple	81 (27)	100 (33.3)
	Other	24 (8)	9 (3)
	Vaccine not applied	144 (48)	137 (45.7)
Time after vaccination			
	Hours	111 (37)	160 (53.3)
	Days	53 (17.7)	34 (11.3)
	Weeks	3 (1)	2 (0.7)
	Unknown	33 (11)	16 (5.3)
	Vaccine not applied	100 (33.3)	88 (29.3)
Number of doses of vaccine received			
	First	109 (36.3)	101 (33.7)
	Second	48 (16)	66 (22)
	Unknown	43 (14.3)	47 (15.7)
	Vaccine not applied	100 (33.3)	86 (28.6)
Vaccine			
	Biontech/Pfizer	52 (17.3)	77 (25.7)
	Moderna	32 (10.7)	39 (13)
	Astra Zeneca	3 (1)	17 (5.7)
	Other	1 (0.3)	7 (2.3)
	Unknown	122 (40.7)	79 (26.3)
	Vaccine not applied	90 (30)	81 (27)
Feedback			
	Positive	176 (58.7)	240 (80)
	Negative	91 (30.3)	43 (14.3)
	Neutral	25 (8.3)	10 (3.3)
	Unknown	8 (2.7)	7 (2.3)

Table 4
Analysis of posts with most 'likes' (>100) and comments (≥10) according to purpose, source, side effects, type of side effects and patient feedback. Data presented as n and percentage (%).

		Twitter	Instagram
Purpose			
	Patient experience	20 (64.5)	29 (82.9)
	News	7 (22.6)	3 (8.6)
	Academic	4 (12.9)	2 (5.7)
	Advertisement	0	1 (2.9)
Source			
	Patients	14 (45.2)	29 (82.9)
	News	10 (32.3)	0
	Professionals	4 (12.9)	2 (5.7)
	Other	3 (9.7)	3 (8.6)
	Unknown	0	1 (2.9)
Side effects			
	Yes	15 (48.4)	24 (68.6)
	No	2 (6.5)	4 (11.4)
	Not named	14 (45.2)	7 (20)
Type of side effects			
	Vaccine not applied	16 (51.6)	11 (31.4)
	Multiple	6 (19.4)	15 (42.9)
	Other	5 (16.1)	2 (5.7)
	Pain	2 (6.5)	7 (20)
	Allergical reaction	2 (6.5)	0
Feedback			
	Positive	15 (48.4)	33 (94.3)
	Negative	15 (48.4)	1 (2.9)
	Neutral	1 (3.2)	0
	Unknown	8 (2.7)	1 (2.9)

Instagram posts were distributed as follows. 181 (60.3%) were posted by females, 74 (24.7%) by males and for 45 (15%) gender was unknown. The majority of Instagram posts were in English (292; 97.3%), followed by German (2; 0.7%) and Hindi (2; 0.7%), and other languages of 1 (0.3%) post each, respectively. The country of origin was mainly the US (179; 59.7%), followed by 74 (24.7%) unknown posts, 20 (6.7%) from UK, 9 (3%) from India, 5 (1.7%) from Canada, 2 (0.7) posts each respectively from Germany, United Arab Emirates and Denmark, and furthermore 1 (0.3%) post each respectively from other countries. The analysis of Instagram post type showed that the majority of posts were videos (104; 34.7%), followed by single photographs (92; 30.7%), text and multiple photographs (52; 17.3%), respectively. The Instagram post purpose assessed a majority of patient experiences (205; 68.3%), followed by 63 (21%) posts of news, 23 (7.7%) with academic purpose, 7 (2.3%) advertisements and 2 (0.7%) posts with an unknown purpose. The analysis of source showed 205 (68.3%) Instagram posts by patients, followed by 37 (12.3%) posts from other sources, 35 (11.7%) of news sources, 11 (3.7%) by healthcare professionals, 6 (2%) unknown sources and last 3 (1%) post from a clinic and company, respectively (Table 1).

3.2. Comparison between Twitter and Instagram by number of 'likes' and comments

In accordance with the number of 'likes', 264 (88%) Twitter posts had between 0 and 50 'likes', 5 (1.7%) posts between 51 and 100 as well as 31 (10.3%) posts over 100 'likes'. 261 (87%) of the Twitter posts showed 0 to 5 comments, 9 (3%) posts showed 6 to 10 comments and 30 (10%) posts had more than 10 comments. Descriptive statistics showed a mean of 41.97 (SD 17.145) for Twitter 'likes' and a mean of 3.34 (SD 5.656) for comments.

Furthermore, 230 (76.7%) of Instagram posts had between 0 and 50 'likes', 35 (11.7%) posts between 51 and 100 and another 35 (11.7%) posts over 100 'likes'. 195 (65%) of the Instagram posts showed 0 to 5 comments, 46 (15.3%) posts showed 6 to 10 comments and 58 (19.3%) posts had more than 10 comments. Descriptive statistics showed a mean of 39.27 (SD 17.812) for Instagram 'likes' and a mean of 2.97 (SD 5.582) for comments.

'Likes' and comments were checked as normally distributed variables by Kolmogorov-Smirnov and Shapiro-Wilk test ($p > 0.05$) so that cross-tabulations could be applied. Chi-square test indicated highly statistically significant differences according to 'likes' ($\chi^2 = 25.083$; $p = 0.001$) and comments ($\chi^2 = 44.353$; $p = 0.001$) between Twitter and Instagram (Table 2).

3.3. Analysis of #covidvaccinesideeffects posts by side effect, vaccine and patient feedback

Furthermore, we investigated #covidvaccinesideeffects 600 posts from Twitter and Instagram in accordance with side effects, type of side effects, time after vaccination, count of vaccination, type of vaccine and general patient feedback.

The majority of Twitter posts of this analysis mentioned side effects (156; 52%), 101 (33.7) did not give any information if side effects occurred or not, and 42 (14%) of Twitter posts reported no side effects. The majority according to Twitter did not receive vaccination and reported about side effect types (144; 48%), followed by multiple side effects (81; 27%), 30 (10%) reported pain, 24 (8%) any other side effects, 10 (3.3%) fatigue, 6 (2%) an allergic reaction, 3 (1%) headache and 2 (0.7%) a swelling of the injection site. The time between Twitter post and vaccination was mainly hours (111; 37%), followed by 100 (33.3%) posts that didn't receive vaccination, 53 (17.7%) days after vaccination, 33 (11%) unknown time and 3 posts about side effects (0.5%) weeks after vaccination. The majority of Twitter posts reported after the first vaccination

(109; 36.3%), 100 (33.3%) didn't receive vaccination, 48 (16%) after the second vaccination and 43 (14.3%) remained unknown. The majority of Twitter posts didn't report which vaccine was applied (122; 40.7%), followed by 90 (30%) posts of not vaccinated users, 52 (17.3%) about Biontech/Pfizer, 32 (10.7%) Moderna, 3 (1%) Astra Zeneca and 1 (0.3%) other vaccine. The majority of Twitter feedback was positive (176; 58.7%), followed by 91 (30.3%) negative feedback, 25 (8.3%) neutral and 8 (2.7%) unknown feedback posts.

The majority of Instagram posts of this analysis mentioned side effects (162; 54%), 97 (32.3) did not give any information if side effects occurred or not, and 41 (13.7%) of Instagram posts reported no side effects. The majority according to Instagram did not receive vaccination and reported about side effect types (137; 45.7%), followed by multiple side effects (100; 33.3%), 43 (14.3%) reported pain, 9 (3%) any other side effects, 4 (1.3%) fatigue, 3 (1%) an allergic reaction, 1 (0.3%) headache and a swelling of the injection site. The time between Instagram post and vaccination was mainly hours (160; 53.3%), followed by 88 (29.3%) posts that didn't receive vaccination, 34 (11.3%) days after vaccination, 16 (5.3%) unknown time and 2 posts about side effects (0.7%) weeks after vaccination. The majority of Instagram posts reported after the first vaccination (101; 33.7%), 85 (28.3%) didn't receive vaccination, 66 (22%) after the second vaccination and 47 (15.7%) remained unknown. The majority of Instagram posts didn't receive vaccination but reported about different vaccines (81; 27%), followed by 79 (26.3%) posts of unknown vaccine, 77 (25.7%) about Biontech/Pfizer, 39 (13%) Moderna, 17 (5.7%) Astra Zeneca and 7 (2.3%) other vaccine. The majority of Instagram feedback was positive (240; 80%), followed by 43 (14.3%) negative feedback, 10 (3.3%) neutral and 7 (2.3%) unknown feedback posts (Table 3).

In addition, the analysis of posts with most 'likes' (>100) and comments (≥10) assessed the following results. The 31 selected Twitter posts had the main purpose of patient experience (20; 64.5%), followed by news (7; 22.6%) and academic purpose (4; 12.9%). The main source were patients (14; 45.2%), followed by news (10; 32.3%), professionals (4; 12.9%) and other (3; 9.7%). The majority of patients reported side effects (15; 48.4%), 14 (45.2%) didn't mention side effects and 2 (6.5%) reported about not having side effects. According to the type of side effects the majority of posts were from people who didn't receive a vaccination (16; 51.6%), followed by multiple reported side effects (6; 19.4%), other side effects (5; 16.1%), pain and allergic reaction (2; 6.5%) respectively. The feedback was equally positive and negative (15; 48.4%) respectively and 1 (3.2%) neutral feedback. 35 selected Instagram posts also had the main purpose of patient experience (29; 82.9%), followed by news (3; 8.6%), academic purpose (2; 5.7%) and 1 (2.9%) advertisement. The main source were patients (29; 82.9%), followed by other (3; 8.6%), professionals (2; 5.7%) and unknown user (1; 2.9%). The majority of patients reported side effects (24; 68.6%), 7 (20%) didn't mention side effects and 4 (11.4%) reported about not having side effects. According to the type of side effects the majority reported multiple side effects (15; 42.9%), 11 (31.4%) posts were from people who didn't receive a vaccination, followed by pain (7; 20%) and other side effects (2; 5.7%). The Instagram feedback was mainly positive (33; 94.3%), followed by negative and unknown (1; 2.9%) respectively (Table 4).

3.4. Analysis by three examiners of different educational level

One hundred Twitter and one hundred Instagram posts by #covidvaccinesideeffects were analyzed by three examiners of different educational level in accordance to their educational quality (poor, moderate and excellent).

The medical student rated 58 Twitter posts of poor educational quality, followed by 35 moderate and 7 posts with excellent educational quality. The resident rated 55 poor, 41 moderate and 4 of the Twitter posts excellent. The senior consultant rated 69 of poor, followed by 26 of moderate and 5 of the 100 Twitter posts of excellent educational quality.

The analysis of the interrater reliability between all three examiners in accordance to the Twitter post rating presented a high concordance with 86% and a highly significant *P* value of p = 0.001.

Furthermore, medical student rated 43 Instagram posts of poor educational quality, followed by 51 moderate and 6 posts with excellent educational quality. The resident rated 52 poor, 45 moderate and 3 of the Instagram posts excellent. The senior consultant rated 82 of poor, followed by 15 of moderate and 3 of the 100 Instagram posts of excellent educational quality.

The analysis of the interrater reliability between all three examiners in accordance with the Instagram post rating presented a high concordance with 81% and a highly significant *P* value of p = 0.001 (Table 5).

4. Discussion:

A social media platform is defined as an internet-based application that offers a digital interaction and a sharing of information, texts, photographs and videos through virtual communities. Twitter e.g., enables a total of 280 characters per tweet [22]. Instagram e.g., was intentionally built to share images, photographs and short videos. Daily, more than 100 million texts, photographs or videos are uploaded and thus patients have quick and easy access to information about health related topics [16]. We conducted this study, to investigate the content of posts in accordance with COVID-19 pandemic, its vaccination and side effects shared by #covidvaccinesideeffects on Twitter and Instagram to evaluate their informational and educational quality.

The COVID-19 pandemic further catalyzed the use of social media applications like Twitter and Instagram for a rapid dissemination and spread of information about this unknown and contagious worldwide disease from reporters, clinics, healthcare professionals, patients and several different sources [13]. Physicians, healthcare professionals and public health organizations like the US Centers for Disease Control and Prevention (CDC) and World Health Organization also use social media platforms to spread information to health care professionals and the general public from verifiable sources [13,23]. The above mentioned rapid and efficient information dissemination characterizes the significant influence that social media possesses on the spread of medical information and knowledge during COVID-19 pandemic [13].

With regard to our study and the influence of the two analyzed applications, our data indicate that the number of 'likes' shows significant differences between Twitter and Instagram. While Twitter shows significant more 'likes' between 0 and 50, Instagram presents more posts with 51 to 100 and more than 100 'likes' per post. In accordance to comments similar and also significant results could be found. However, both platforms present a majority of posts with a minority of 'likes' and comments. In addition, the number of 'likes' and comments does not give any information about the quality of posts. A further analysis of 31 Twitter and 35 Instagram posts with the majority of 'likes' and comments couldn't show severe differences compared with all analyzed posts irrespective of number of 'likes' and comments regarding purpose, source, side effects, type of side effect and patient feedback. Thus, a better quality of posts with more 'likes' and comments couldn't be assessed for our cohort. The number mainly shows agreement or disagreement of other users. Nevertheless, the percentage of posts by professionals increased according to this analysis.

In our investigation, we got the impression of more detailed, high quality posts by professionals. While in general 2% of posts were posted by healthcare professionals respective for Twitter

Table 5
Evaluation of educational quality of 100 Twitter and 100 Instagram posts by a student, resident and senior consultant medical doctor. Data presented as n and significance of interrater reliability.

	Twitter			Instagram		
	Student	Resident	Consultant	Student	Resident	Consultant
Poor	58	55	69	43	52	82
Moderate	35	41	26	51	45	15
Excellent	7	4	5	6	3	3
Interrater reliab.	86 %	F = 7.458	P = 0.001	81 %	F = 7.208	P = 0.001

and Instagram, the analysis of posts with most 'likes' and comments resulted in 12.9% Twitter and 5.9% Instagram posts by professionals. However, further investigations have to be made for a precise comparison between layman and professional posts due to this topic.

The dominant language of posts by #covidvaccinesideeffects is English, followed by German, French and Hindi on Twitter and Instagram, respectively. While the presence of Internet and social media increases, also social media platforms like Twitter and Instagram continue the distribution of health-related information especially during COVID-19 pandemic [16,24]. There are several parameters why social media platforms have affected healthcare related topics and thus built a source of patient information. The use of social media increased in the United States between 2005 and 2017 from 5 to almost 70 percent [16]. Majority of users also view and share posts on these platforms more than once per day [16]. Furthermore, mentioned platforms require detailed information about their users, such as age, gender, or even interests [25]. A user targeted advertisement is distributed by sharing this information [25]. Social media platforms are used for advertisement and spreading information in several sectors and healthcare professionals as well as clinics may benefit significantly from using them [26,27]. Therefore, it is important to understand how patients, physicians and companies use these media sites, compare these platforms to one another and evaluate the shared information.

The analysis in accordance with the type of post assessed a majority of texts, followed by single photographs and videos for Twitter. Instagram presented a majority of videos followed by single photographs and a minority of multiple photos and text. These results are also in line with previously published data [15]. But a different structure and purpose of these social media platforms has to be taken into account. While Twitter aims for short messaging, Instagram is the preferred platform for sharing photos and videos [16]. Irrespective of medical topics, other investigations also elucidated a majority of photographs, followed by videos and a minority of text contributions [15,16,28].

In addition, our analysis of unfiltered posts elucidated, that the purpose of posts by #covidvaccinesideeffects showed mainly patients experiences followed by news articles for Twitter and Instagram, respectively. Only 6.6% Twitter and 4.7% Instagram posts had an academic background and were posted by a professional or a clinic. Irrespective of professionals, the challenge for patients and nonprofessionals is to evaluate the multitude of unfiltered social media information towards useful, relevant and especially correct information.

Furthermore, what are the reasons for patients using social media platforms due to medical related information? Several studies investigated patients sharing their treatment experiences [17,20,28]. Patients may also want to add their knowledge by social media medical information even more than they do in a doctor's interview or even before consulting a doctor [29]. This could be one issue that makes patients turn to the Internet and social media as a source of specific medical information [15,30]. Nevertheless, reliability and quality of texts, photographs and videos posted on Instagram are controversial. As a public platform, everyone can share his or her opinion and unreviewed content.

In part 3 of our study, we assessed the social media content in accordance with COVID-19 vaccination and its side effects. About 50% of posts respective on Twitter and Instagram mentioned side effects. Mainly side effects like pain or swelling at injection site, fatigue or cephalgia were reported. These types of side effects are in line with the first approved and in our study mentioned COVID-19 vaccines by Biontech/Pfizer, Moderna, Astra Zeneca and Johnson & Johnson [31]. In accordance with the two mRNA- and two vector-vaccines symptoms like pain, fever, fatigue and cephalgia are described [6,31–33]. These mild effects occur by about 70% after the first injection and about 65% after the second dose [33]. In our study 52% of posts mentioned side effects. Interestingly, in accordance with the type of side effect the majority of posts were provided by sources that didn't receive a vaccination. 48% of Twitter and 45.7% of Instagram posts about side effects were posted by people who didn't receive COVID-19 vaccination. This fact gives an impression about reliability and misguidance of online spread information regarding medical and also general information. Thus, it's understandable that one person with side effect is shared by several online. Therefore, it's even more important to compare social media data of medical topics with scientific studies and discuss such influencing parameters.

Posts from people who received a vaccine were mainly mild and about pain at injection site, fatigue or cephalgia. The majority of patients received vaccines from Biontech/Pfizer, Moderna, Astra Zeneca and Johnson & Johnson and posted within hours after the first vaccination. The general feedback was majorly positive with about 60% of Twitter and 80% of Instagram posts. For the period of our analysis the above mentioned two mRNA- and two vector-vaccines have been approved in several countries [34]. Thus, the content about these vaccines is nearby. Interestingly, while in public media mainly severe side effects like intracranial venous sinus thrombosis and myocarditis are reported, they are not discussed by social media posts of our study and mainly mild side effects were reported [35,36]. This effect might be caused by the incidence and occurrence of these side effects [34]. Generally, the reported side effects concur with clinical data from ongoing studies [34]. Nevertheless, it should be taken into account that the occurrence of side effects mentioned by social media posts is difficult to compare with clinical data from scientific studies. For sure, it is more nearby to post about having side effect if they occur or even hearing from other patients occurring than not having side effects at all and reporting about them.

The timeline January to April of this analysis and the respectively selected 300 posts might be the main limitations of our study. Beginning in January 2021 we investigated the first 300 posts on Twitter and Instagram by #covidvaccinesideeffects. While for this period a few more than 300 posts by this hashtag were posted on these applications, a comparable number of the first 300 each has been chosen. Besides the above-mentioned approved medication, elderly people and healthcare workers were the first with access to COVID-19 vaccination. In addition, western countries like the US and EU started with a broadly

available vaccination program first. These facts could have influenced our results due to language, country of origin, purpose, source and also attitude towards vaccination, side effects and general feedback. Interestingly, only 2% of posts could be identified by healthcare professionals, respectively. While more than 60% were identified as posted by patients. Due to limited information in many cases a precise source couldn't be clearly identified. However, further studies should be conducted to investigate a longer timeline and a larger number of posts by a worldwide user collective.

The spread of information and misinformation by social media about vaccination in general has been investigated before [37–39]. Ortiz-Sanchez et al. report about a spread of false information on social media regarding the COVID-19 pandemic. They explain the fact of misinformation by the novelty of the disease and besides due to its origin and different treatment strategies [37]. False information like doubt of existence of the virus or microchip implantation by vaccination occur [37]. The study of Ortiz-Sanchez et al. on anti-vaccination movements on social media encourages healthcare professionals, health organizations and social networks to prevent the dissemination of fake information by these platforms [37]. However, due to our data a minority of false information but mainly unqualified and unvalidated information was recorded. Furthermore, the majority of posts reported a positive feedback according to the COVID-19 vaccination.

For analysis of educational quality 100 consecutive Twitter and Instagram posts were evaluated by three investigators of different educational level. The majority of contributions were rated by the examiners as "poor" or "moderate". Only 3–5% of posts were rated "excellent" by a senior consultant, followed by almost 3–4% rated "excellent" by a resident and 6–7% by a medical student. Which means, containing sufficient and substantial information, that is useful for other users or even patients and coincides with the majority of scientific knowledge. A high and significant interrater reliability of 86% for Twitter and 81% for Instagram was detected between the examiners. Our results demonstrate that observers with general medical knowledge perform a similar evaluation of #covidvaccinesideeffects posts. While a higher level of medical education also leads to a more critical evaluation.

A study by Hegarty et al. evaluated treatment videos on YouTube by the highest number of viewers [20]. They assessed more than 50% of the videos presented low quality information and videos with informative content had a percentage of about 9% [20]. These results are very similar to our data due to COVID-19 vaccination. In addition, Hegarty et al. also noted that most videos were about patient experiences and thereby lead to high degree of bias [20]. Thus, they conclude that YouTube videos about treatment procedures were not recommendable for treatment and that patients should be advised to view it with caution. Our investigation supports this deduction. The majority of content on Twitter and Instagram about COVID-19 vaccination were shared by patients. The information sources were frequently unclear, therefore they are limited in reliability. Irrespective of topics like vaccination, medical treatment or surgery, previous studies and our investigation could proof these results [16,17,20,24,37]. Nevertheless, the influence of social media on medical and healthcare information is increasing and besides academic, educational information, practitioners have to face its effect on their patients. Twitter and Instagram as worldwide content provider offer a platform for presenting and sharing medical information which facilitates patients and professional an easily accessible way of communication and compulsory validated information especially during a worldwide pandemic like COVID-19.

5. Conclusions:

Social media platforms like Twitter and Instagram offer a multitude and worldwide accessible information. Since the beginning of COVID-19 pandemic the exchange of medical information about several topics and opinions in accordance to this infectious disease and its vaccination has increased rapidly. While assorted information in accordance to COVID-19 vaccination is available, only few is validated by professionals and can be evaluated by excellent educational quality. While a majority of posts by #covidvaccinesideeffects report about the occurrence of side effects, the majority of them were mild and general COVID-19 vaccination feedback during the first 4 months was positive. However, a majority of posts presented opinions or even misinformation. Due to our analysis, only 3 to 7% were rated by "excellent" educational and validatable content. For the majority of patients, it is challenging to evaluate the quality of medical information. But the influence of social media on medical and healthcare information is rapidly increasing and practitioners have to face misinformation and its effect on their patients.

Ethical approval

Due to public data and the pure retrospective nature of this investigation, local ethics committee exempts this study from a specific ethics vote. Patients' data were treated confidentially and anonymized when extracted from the files. The study was conducted in accordance with the ethical principles of the declaration of Helsinki and its further amendments.

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CRediT authorship contribution statement

Max-Philipp Lentzen: Conceptualization, Supervision, Writing - original draft. **Viola Huebenthal:** Data curation, Investigation. **Rolf Kaiser:** Validation. **Matthias Kreppel:** Supervision. **Joachim E. Zoeller:** Validation. **Matthias Zirk:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

All the authors have made substantial contributions to the final version of the submitted manuscript. Max-Philipp Lentzen designed the study, performed data acquisition, analyzed and interpreted the data, drafted the manuscript and critically reviewed the manuscript. Viola Huebenthal performed data acquisition. Rolf Kaiser, Matthias Kreppel and Matthias Zirk analyzed and interpreted the data, and critically reviewed the manuscript. Matthias Zirk, Matthias Kreppel and Joachim E. Zoeller performed data acquisition, analyzed and interpreted the data, drafted the manuscript and critically reviewed the manuscript. All the authors read and approved the final version of the article.

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