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# Clinical characteristics and outcomes of measles outbreak in adults: A multicenter retrospective observational study of 93 hospitalized adults in Greece

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## ABSTRACT

**Objectives:** Measles outbreaks are increasingly reported among countries that were close-to-eliminate measles infection. There are few reports of clinical characteristics of measles in adults in the contemporary literature. In this study we aim to describe the clinical characteristics and complications of measles infection in hospitalized adults during the recent epidemic in Greece.

**Methods:** A multicentre observational retrospective study was conducted in three tertiary hospitals in Greece. All adult hospitalized patients ( $\geq 18$  years old) with serologically confirmed and/or clinical features compatible with measles were included. Pediatric patients and patients with missing data were excluded.

**Results:** In total, 93 patients, 40 males (43 %) and 53 females (57 %), mostly young patients were included. Most of them (87 %) had no past medical history. Among women, 4 were pregnant. 56 (60.2 %) and 25 (26.9 %) patients reported either unknown or incomplete vaccination for measles. Ribavirin was administered in 8 (8.6 %) patients. Pneumonitis and hepatic involvement were the most common complications, occurring in 43 (46.2 %) and 75 (80.6 %) patients respectively. Pneumonitis was significantly associated with male sex, older age, lower lymphocyte counts and higher C-reactive protein (CRP) on admission. One pregnant woman suffered spontaneous fetal miscarriage and one patient died due to acute respiratory distress syndrome (ARDS) and high-risk pulmonary embolism.

**Conclusion:** Considerable proportions of incompletely vaccinated or unvaccinated adults have led to the re-emergence of measles in countries with reported close-to-elimination rates. Pneumonitis is a major complication among adults with measles. More studies are imperative in order to explore the role of immune paresis in measles.

## 1. Introduction

Measles infection is a highly contagious, air-borne, acute febrile illness caused by a paramyxovirus of the *Morbillivirus* genus [1] and still

remains an unresolved global issue with considerable mortality and morbidity rates [2]. The World Health Organization (WHO) has recently reported an upsurge of measles cases in the Eastern Mediterranean, the European and the Americas Regions, in areas with reported

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close-to-elimination or elimination of measles [2–4]. The re-emergence of measles infection possibly signifies the gap in previous vaccination strategies. According to the latest WHO-UNICEF report only five European countries reported >95 % vaccination coverage with both doses of measles-containing vaccine; the respective rates in Greece for the first and second dose were 97–99 % and 77–83 % between 2008–2018 [5]. Although the epidemic was contained in Greece during 2019, there was a substantial upsurge in other European countries during the same year with a total of 13,460 cases [6]. Similarly, an outbreak with 1282 cases (of whom 29 % adults) was reported in the United States of America (USA) during 2019, a country that declared measles elimination in 2000 [7].

The natural course of the infection has only been scantily defined in adults, making management challenging even for experienced clinicians. In this study, we describe our experience from the recent outbreak of measles in adult hospitalized patients in Greece [8].

## 2. Patients and methods

### 2.1. Data collection

We conducted a multi-centre retrospective observational study of adult patients with measles in three tertiary teaching hospitals in Greece (Attikon University Hospital of Athens – AUH, Hippokraton General Hospital of Athens – HGH and Thriasio General Hospital – TGH) between October 2017 and September 2019. All adult patients ( $\geq 18$  years old) with compatible clinical features and/or serologically confirmed measles requiring hospitalization were included. Measles antibodies were measured with Enzyme-linked Immunosorbent Assay (MEASLES ELISA IgG/IgM kit, Vircell, Grenada, Spain). Patients with multiple missing data were excluded. All cases were then adjudicated with regards to clinical course, complications and/or outcome by three senior clinicians.

### 2.2. Ethics statement

This study was approved by the Research Ethics Committee of each participating institution (protocol numbers: AUH: 1821A/22–9-16, TGH: 433/18–12-19, HGH: 2613/18–2-2020) and was conducted according to the Outbreak Reports and Intervention studies Of Nosocomial infection (ORION) reporting guidelines [9]. Patients' data were collected and analyzed under strict anonymity in agreement with the Declaration of Helsinki. Since this was a retrospective study, no informed consent was obtained.

### 2.3. Definitions

All patients were classified either as probable or as confirmed cases according to the case classification by the European Centers for Disease Control and prevention (ECDC) (Table 1). Definitions of pneumonitis and hepatic involvement are provided in Table 1.

### 2.4. Statistical analysis

Demographic and descriptive continuous variables with normal distribution are reported as mean (standard deviation, SD), whereas non-normally distributed data are presented as median values (interquartile range, IQR). Categorical variables are expressed as percentages. Chi square or Fisher's exact test was used for comparison of dichotomous and Mann-Whitney or *t*-test for continuous variables. Univariate and multivariable logistic regression analysis was used in order to identify baseline factors associated with pneumonitis. Variables that were statistically significant in univariate analyses ( $p < 0.1$ ) were included in the multivariable model. Variables of biological significance (sex and age), were retained until the final stage of multivariable analysis (backward selection). Outcomes of logistic regression analysis are

**Table 1**  
Definitions of measles cases, pneumonitis and hepatic involvement.

Condition	Definition
Probable case of measles infection [10]	Any person meeting the <i>clinical criteria</i> with an <i>epidemiological link</i> . Clinical Criteria: Fever <b>AND</b> Maculo-papular rash <b>AND</b> at least one of: Cough, Coryza, Conjunctivitis. Any person not recently vaccinated and meeting the <i>clinical</i> and the <i>laboratory criteria</i> Clinical Criteria: Fever <b>AND</b> Maculo-papular rash <b>AND</b> at least one of: Cough, Coryza, Conjunctivitis. <b>AND</b>
Confirmed case of measles infection [10]	Laboratory Criteria: At least one of: Isolation of measles virus from a clinical specimen <b>AND/OR</b> Detection of measles virus nucleic acid in a clinical specimen <b>AND/OR</b> Measles virus specific antibody response characteristic for acute infection in serum or saliva <b>AND/OR</b> Detection of measles virus antigen by DFA in a clinical specimen using measles specific monoclonal antibodies The presence of cough and/or dyspnea <b>AND</b>
Pneumonitis	Clinical signs and/or imaging compatible with lower respiratory tract infection. Elevation of ALT above the ULN on admission (according to each centre's reference range)
Hepatic involvement	The severity was divided into 2 Grades; Grade I: ALT $\leq 5 \times$ ULN Grade II: ALT $> 5 \times$ ULN.

ALT: Alanine aminotransferase, DFA: Direct fluorescent antibody, ULN: Upper limit of normal.

displayed as odds ratios (OR) and their respective 95 % confidence intervals (95 %CI). All statistical analyses were two-tailed and performed with SPSS (IBM SPSS Statistics for Windows, v. 20.0. Armonk, NY: IBM Corp) and Stata 12 (StataCorp).

## 3. Results

### 3.1. Demographics

In total 93 patients, 40 males (43 %) and 53 females (57 %) aged between 18 and 62 years old, were included (Table 2).

Most patients were immunocompetent and young, with only 4 (4.3 %) being > 50 years old. Among the 53 women, 4 (7.5 %) were pregnant. Seventy-two patients (77 %) had serologically confirmed measles with positive IgM antibody on admission. From the remaining 21 patients, 12 (13 %) had probable infection with negative serology on admission despite of the compatible clinical presentation, whereas serological testing was not performed in 9 (10 %) patients. Fifty-six (60.2 %) and 25 (26.9 %) subjects had either unknown or incomplete vaccination status (1 dose) for measles, with the combined measles/mumps/rubella (MMR) vaccine, respectively. Twelve (12.9 %) patients reported no MMR vaccination. Treating physicians considered all included measles cases as primary infections and none of the patients reported a prior measles infection.

### 3.2. Signs, symptoms and laboratory results

All 93 patients presented with high grade fever ( $> 38.5^\circ\text{C}$ ), while 89 (95.7 %) patients developed generalized rash. Other common symptoms and signs were cough (55.9 %), Koplik spots (34.1 %), gastrointestinal symptoms (31.9 %) and pharyngitis (30.1 %) (Table 2). Laboratory results are summarized in Table S1.

### 3.3. Pneumonitis

In total, 43 (46.2 %) patients (24 men) fulfilled the definition of pneumonitis. No bacterial superinfections were diagnosed. Pneumonitis

**Table 2**  
Patient demographics and clinical characteristics.

Demographics	
Female (n, %)	53 (57 %)
Age [mean (SD)]	32.6 (10.2)
Pregnancy (n, % of female)	4 (7.5 %)
Days of symptoms before admission [median (IQR)]	4 (3–5)
Antibiotic use during disease course (n, %)	55 (59.8 %)
Ribavirin (n, %)	8 (8.6 %)
Vaccination status (n, %)	
None	12 (12.9 %)
Incomplete	25 (26.9 %)
Unknown	56 (60.2 %)
Ethnicity (n, %)	
Non-Greek	19 (20.4 %)
Greek	74 (79.6 %)
Roma ethnic subgroup (% of Greek patients)	11 (14.9 %)
Comorbidities (n, %)	
None	81 (87 %)
Diabetes	4 (4.3 %)
Chronic pulmonary disease	6 (6.5 %)
Coronary artery disease	5 (5.4 %)
Heart failure	2 (2.2 %)
Current cancer	0 (0%)
Cirrhosis	1 (1.1 %)
Symptoms and signs, n (%)	
Rash	89 (95.7 %)
Cough	52 (55.9 %)
Koplik spots	30 (34.1 %)
GI symptoms	29 (31.9 %)
Pharyngitis	28 (30.1 %)
Conjunctivitis	27 (29 %)
Nasal discharge	16 (17.2 %)
Lymphadenopathy	14 (16.1 %)
Dyspnea	10 (10.8 %)
Complications, n (%)	
Pneumonitis	43 (46.2 %)
Hepatic involvement	75 (80.5 %)
Grade I	47 (50.5 %)
Grade II	28 (30.2 %)
Outcomes	
Discharged (n, %)	92 (98.9 %)
Died (n, %)	1 (1.1 %)
Hospitalization in days [median (IQR)]	6 (4–7)

GI: gastrointestinal, IQR: interquartile range, n: number of patients, SD: standard deviation.

was more prevalent among male compared to female patients (60 % vs. 36 %,  $p = 0.02$ ). Furthermore, the patients in pneumonitis group were significantly older than those without pneumonitis ( $36.3 \pm 11.1$  vs.  $29.5 \pm 8.2$  years old,  $p = 0.001$ ) (Table 3).

The lymphocyte count on admission as well as the lymphocyte nadir count, were both significantly lower in the pneumonitis group ( $490 \times 10^6/L$  vs.  $740 \times 10^6/L$ ,  $p = 0.006$  and  $420 \times 10^6/L$  vs.  $610 \times 10^6/L$ ,  $p = 0.005$  respectively) (Table 3). Patients with pneumonitis received antibiotics more frequently ( $p = 0.02$ ). Neither duration of symptoms before admission nor any specific symptoms or signs were significantly associated with the presence of pneumonitis. In multivariable analysis, both female sex and higher lymphocyte counts on admission had a protective effect against pneumonitis (OR = 0.26, 95 % CI: 0.09–0.752 and OR = 0.997, 95 % CI: 0.995–0.999 respectively) (Table 4). On the contrary, advanced age and C-reactive protein (CRP) were independently associated with the development of pneumonitis (OR = 1.14, 95 % CI: 1.038–1.249 and OR = 1.07, 95 % CI: 1.013–1.14) (Table 4).

Intravenous ribavirin administered in 8 (18.6 %) patients with pneumonitis and, compared to those who were managed conservatively, tended to be prescribed in numerically lower arterial partial oxygen pressure to inspired oxygen fraction ( $PaO_2/FiO_2$ ) ratios, without prolongation of hospitalization correlation (Table 5). Of note, most of the

**Table 3**  
Comparison of patients with and without pneumonitis.

Variable	Pneumonitis group (n = 43)	No pneumonitis group (n = 50)	p value
Age [mean (SD)]	36.3 (11.1)	29.5 (8.2)	<b>0.001</b>
Female (n, %)	19 (44)	34 (68)	<b>0.02</b>
Vaccination status (n, %)			<b>&lt;0.001</b>
None	6 (14)	6 (12)	
Incomplete	20 (46.5)	5 (10)	
Unknown	17 (39.5)	39 (78)	
Antibiotic use (n, %)	31 (72)	24 (49)	<b>0.02</b>
Symptoms duration before admission in days [median (IQR)]	4 (3–5)	4 (3–5)	0.54
Hospitalization duration in days [median (IQR)]	6 (3)	5 (3)	0.37
Conjunctivitis (n, %)	16 (37)	11 (22)	0.10
Lymphadenopathy (n, %)	4 (10)	10 (21)	0.15
Nasal discharge (n, %)	10 (23)	6 (12)	0.15
Rash (n, %)	42 (98)	47 (94)	0.38
Koplik spots (n, %)	13 (32)	17 (36)	0.66
Pharyngitis (n, %)	12 (28)	16 (32)	0.67
GI symptoms	13 (30)	16 (33)	0.75
WBC count ( $\times 10^9/L$ ) [mean (SD)]	4.7 (1.9)	4.9 (2.5)	0.72
Lymphocyte count nadir ( $\times 10^6/L$ ) [mean (SD)]	420 (220)	610 (400)	<b>0.005</b>
Lymphocyte count on admission ( $\times 10^6/L$ ) [mean (SD)]	490 (290)	740 (510)	<b>0.006</b>
Neutrophil count on admission ( $\times 10^9/L$ ) [mean (SD)]	4.1 (1.7)	3.9 (2.4)	0.68
Monocyte count on admission ( $\times 10^6/L$ ) [mean (SD)]	441 (280)	400 (254)	0.46
CRP (mg/L) [mean (SD)]	40.5 (25.0)	54.6 (38.7)	<b>0.04</b>
ALT, U/L [mean (SD)]	149 (146)	148 (124)	0.97

ALT: alanine aminotransferase, CRP: C-reactive protein, GI: gastrointestinal, IQR: interquartile range, L: liter, n: number of patients, SD: standard deviation, U: units, WBC: white blood cell count.

**Table 4**  
Multivariable analysis for pneumonitis risk factors.

Variable	OR	Lower 95 % CI	Upper 95 % CI	p value
CRP (mg/L)	1.07	1.013	1.14	0.017
Female sex	0.26	0.09	0.752	0.013
Age	1.14	1.038	1.249	0.006
Total lymphocyte count ( $\times 10^6/L$ )	0.997	0.995	0.999	0.002

CI: confidence intervals, CRP: C-reactive protein, L: liter, mg: milligram, OR: odds ratio.

Age-CRP interaction was also included in the final model, however it was non-significant.

ribavirin-treated patients (7/8) were from one of the participating centers.

### 3.4. Other complications

Hepatic involvement was found in 77 (82.8 %) patients. Among them, 47 (50.5 %) and 28 (30.2 %) patients had Grade I and Grade II hepatic involvement respectively. When patients divided into those without or with Grade I liver injury and those with Grade II hepatic involvement, no statistically significant differences regarding baseline characteristics and presenting symptoms or signs were noted apart from the gastrointestinal (GI) symptoms that were more frequent in those without or with Grade I liver involvement (Table S2). A similar comparison between those with normal alanine aminotransferase (ALT) and those with any degree of hepatic involvement did not reveal any

**Table 5**

. Characteristics and outcomes of ribavirin group in patients with pneumonitis and hepatic involvement.

Variable	Pneumonitis			Hepatic involvement		
	Ribavirin (+) (n = 8)	Ribavirin (-) (n = 35)	p value	Ribavirin (+) (n = 6)	Ribavirin (-) (n = 69)	p value
Lymphocyte count nadir (x10 <sup>6</sup> /L) [mean (SD)]	541 (186)	389 (221)	0.08	546 (197)	505 (327)	0.76
Lymphocyte count on admission (x10 <sup>6</sup> /L) [mean (SD)]	718 (389)	447 (241)	0.15	781 (429)	583 (381)	0.23
PaO <sub>2</sub> /FiO <sub>2</sub> ratio* [mean (SD)]	254 (63)	297 (65)	0.17	262 (65)	379 (70)	<b>0.001</b>
Hospitalization duration in days [median (IQR)]	7.5 (6–9)	6 (4–7)	0.28	7.5 (5.75–9)	6 (5–7)	0.24
Age [mean (SD)]	38 (16.2)	35.9 (9.8)	0.65	36 (18.4)	32 (9.4)	0.48
Female, n (%)	4 (50)	15 (43)	0.71	3 (50)	39 (56.5)	0.76
ALT (U/L) [mean (SD)]	141 (188)	151 (138)	0.86	179 (206)	179 (126)	0.99

\*Data from 21 patients (pneumonitis comparison) and 46 patients (hepatic involvement comparison).

ALT: alanine aminotransferase, FiO<sub>2</sub>: fraction of inspired oxygen, IQR: interquartile range, L: liter, n: number of patients, PaO<sub>2</sub>: arterial partial pressure of oxygen, SD: standard deviation, U: units.

statistically significant difference.

A patient with confirmed measles was presented with a generalized vasculitic eruption instead of the typical rash, while another two males developed haematuria with dysmorphic red blood cells in urine sediment, suggestive of acute glomerulonephritis. In one of them, further work-up with C3, C4, rheumatoid factor and immunoglobulin levels disclosed normal values. Furthermore, 1 out of the 4 pregnant women suffered spontaneous fetal miscarriage during her hospital stay at the 8th week of gestation. No neurological complications were reported in this cohort.

### 3.5. Outcomes

All but one patient, were discharged alive from hospital after a median hospitalization of 6 days (IQR = 4–7). Pneumonitis was not correlated with the length of hospital stay (Table 3). One obese female patient with a Grade II hepatic involvement and pneumonitis that progressed rapidly into acute respiratory distress syndrome (ARDS) requiring mechanical ventilation, died within 6 days of her admission due to high-risk pulmonary embolism (PE) despite being treated with ribavirin.

## 4. Discussion

In this study we describe the clinical features and outcomes of mostly healthy and young adult hospitalized patients with measles. Our data show that the most prevalent symptoms and signs are high-grade fever, cough and generalized maculopapular rash in concordance with previous reports in adults [11,12]. Hepatic involvement and pneumonitis frequencies were as high as 80.6 % and 46.2 % respectively. When compared to other recent studies including adults, our cohort was quite similar in terms of mean age, sex distribution, presenting symptoms and baseline laboratory findings [13]. Despite the high prevalence of pneumonitis in this study, case fatality rate remained low (1.1 %), possibly explained by the cohort's characteristics (young previously healthy patients). Low case fatality rates were also reported in Europe (10/13,460, 0.007 %) and in the USA, where no deaths were reported to the CDC during the 2019 outbreak [7].

MMR vaccine was introduced in the Greek National Immunization Program in 1989 for all who were born after 1970. During the latest outbreak, the schedule was revised and it currently includes two mandatory doses with the first administered in children aged between 12–15 months and the second between the age of 24–47 months. Genotype B3 was the most commonly circulating strain during the 2017–2019 outbreak [8]. On the contrary, genotypes D4 and D6 co-circulated during a major outbreak occurred between 2005–2006 [14].

Pneumonitis is probably the most serious complication of measles. The prevalence of pneumonitis in our study (46.2 %) was slightly higher than the one recently reported in Israel (30.5 %), in Serbia (26.8 %) and China (33 %), although the latter two studies included pediatric and

adolescent cases that could have affected the pooled results [13,15,16]. Here, we show that male sex, older age, higher CRP and low lymphocyte counts are significantly associated with the presence of pneumonitis. To our knowledge, only one recent study has focused on identifying risk factors for pneumonitis. Tu et al. reported that measles-associated pneumonia was associated with younger age, longer fever duration, higher white blood cell (WBC) counts and normal ALT [16]. Again, we believe that the inclusion of all age groups in this analysis may have a significant impact on the outcomes, making the extrapolation of the results in adults less sounding. Indeed, children <8 months old had significantly higher rates of pneumonitis; moreover, normal lymphocytosis of childhood may have attenuated the impact of lymphopenia as an independent associated factor for pneumonitis.

Another interesting finding is the low proportion of patients with Koplik spots seen in our cohort (30.4 %). This could be possibly attributed to the long median time from symptom onset to hospital admission (4 days), given that Koplik spots appear 1–2 days prior to skin rash and usually disappear within the second day of rash eruption.

Measles-induced lymphocytopenia as well as its grade, possibly has a role either as a disease severity biomarker or as a predisposing factor for short- and long-term infectious complications. There is growing evidence that measles infection induces immunosuppression; a recent study in measles-infected children found significantly higher rates of hospitalization (during the first month), of non-measles infections and of antimicrobial prescriptions up to 5 years post-measles, compared to children without measles [17]. Mina et al. showed that measles infection, but not MMR vaccination, reduces the humoral immune memory against numerous viruses in children [18]. Another study demonstrated that measles compromises the protection acquired by vaccinations or previous infections by altering the memory B-lymphocyte diversity and leads to incomplete naïve B-cell reconstitution, characterized by a narrower post-infection B-cell receptor repertoire [19].

Although it is generally believed that CRP is not increased in patients with viral infections in the absence of pneumonitis, several studies have shown modest increases of CRP in patients with influenza and other viruses even in the context of non-severe disease sparing the lower respiratory tract [20–22]. As for measles, Griffin et al. reported in an older study including children, 4- to 5-fold increases in CRP even in uncomplicated cases. In concordance with the above, we do not consider the increased CRP in our patients with and without pneumonitis unusual [23].

Diagnosis of pneumonitis was followed by antibiotic prescription in 72 % of patients, though we had no proven superinfections in this cohort. In contrast, an older study by Loukides et al. reported a bacterial pneumonia rate of 26 % in measles-infected young males during an epidemic in the Greek army, with *Streptococcus pneumoniae* and *Klebsiella pneumoniae* being the most commonly isolated pathogens [24].

In our cohort, only 8 patients received ribavirin. Due to the small number of treated patients and the heterogeneity in its use among the participating centers, our study could not reach to any specific conclusions regarding its exact role in the management of patients with

measles. Ribavirin use in this setting is mainly supported by case reports or small case series [25,26].

Only one death was seen among 93 patients. This case was a 36-year old previously healthy female who developed measles-induced ARDS and PE with hemodynamic instability. The interplay between viruses and pro-coagulant state has been previously reported; influenza has been associated with acute coronary syndromes [27] and possibly de novo PE in the absence of deep venous thrombosis [28], while similar cases have also been reported with other viral infections [29]. Apart from obesity, our patient did not have any other risk factors for PE, in agreement with a recently reported pediatric case [30]. This potentially fatal complication could be attributed to direct endothelial damage caused by the measles virus, given that endothelial dysfunction has already been reported in children with fatal measles encephalitis [31]. This particular complication in acutely ill patients with respiratory viral infections has become even more relevant in light of the COVID-19 pandemic, where venous thromboembolism (VTE) is increasingly reported, even in the presence of prophylaxis [32]. Moreover, some evidence supports a survival benefit with VTE treatment in critically ill patients with COVID-19 (but not in those with non-COVID-19 illness) and increased D-dimers [33]. Current guidelines show significant divergence ranging between more conservative [34] and more liberal approaches [35]. Regarding measles infection, we suggest that hospitalized patients with measles should be treated according to the existing VTE prophylaxis guidelines in patients with acute medical illness.

Another finding of great interest is the disease pattern in pregnant women with measles. In our cohort, 4 women (7.5 % of female patients) were pregnant and we recorded one miscarriage among them (25 %). Pregnant women are more likely to be hospitalized, develop pneumonia and die when compared to non-pregnant women and, although not regularly associated with a higher miscarriage rate, measles has been correlated with preterm labor, low birth weight and higher rates of admission in neonatal ICU [36]. The rate of obstetric complication in our cohort was similar to the one reported by Rafat et al. (25 % vs. 20 %) in a series of adult patients admitted in the ICU [37]. These findings emphasize the need for a robust vaccination program in women of childbearing age before conception.

Strengths of our study are its multicenter design, with the three participating tertiary hospitals covering a substantial area of metropolitan Athens and Western Attica and the patient care by senior infectious diseases physicians in all three hospitals. Furthermore, we present data from a homogenous cohort of immunocompetent adults diagnosed during a short time period. In contrast to other contemporary studies, we focused on clinical and not exclusively on epidemiological aspects. Finally, we identified patient characteristics (age and sex) along with simple and widely available biomarkers (lymphocyte count and CRP) that could facilitate physicians to timely identify adults at high risk for pneumonitis. However, these findings need to be prospectively validated in future studies.

Our study also has some limitations. The retrospective design could attribute to several biases and missing data, although the medical files were thoroughly reviewed and the percentage of missing data was quite low for almost all variables. Moreover, treatment patterns across participating centers were not aligned, as it was depicted in the heterogeneity of ribavirin administration. This is not surprising, given the absence-to our knowledge-of guidelines establishing the role of ribavirin or other antivirals in immunocompetent adult patients with measles. Finally, the inclusion of hospitalized patients may not precisely reflect the physical history of measles-associated pneumonitis in general population, since a proportion of patients with a more indolent lung involvement might not require hospitalization.

In summary, in this study we presented the clinical characteristics of measles infection during the recent epidemic in hospitalized adults in Greece. We further identified independent baseline risk factors for pneumonitis and described several other serious complications. Measles remains an unresolved global issue and clusters of incompletely

vaccinated or unvaccinated populations remain vulnerable during epidemics. Healthcare professionals should compel a high index of suspicion and familiarize themselves with the most common signs, symptoms and complications of measles in adults.

## Author contributions

Conception and design of the study: PCF, DK, ST, TM. Acquisition of data: PCF, KT, TM, EK, MP, GL, ES, SS, HS. Analysis and interpretation of data: KT, MP, HS, SD, ES, SS, ST, DK. Drafting the article: PCF, KT, TM, EK, ES, HS, SD, GL. Revising critically the manuscript for important intellectual content: PCF, KT, MP, ES, SS, SD, ST, DK. All authors approved the final version of the manuscript submitted.

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## Data statement

The data that support the findings of this study are available from the corresponding author [PCF: evita.fragkou@gmail.com] upon request.

## Declaration of Competing Interest

None of the authors has any conflicts to declare.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jcv.2020.104608>.

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