LETTER TO THE EDITORS

Comment on “Stroke in patients with SARS-CoV-2 infection: case series” from a London hospital experience

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Dear Sirs,

We read with interest Morassi et al. case series, [2] where they and others [1, 3] reported stroke as a complication of severe COVID-19 infection. The effect of COVID-19 on acute stroke patients (ischaemic and haemorrhagic) who may catch the disease concomitantly with stroke or after stroke but not as a cause of severe COVID-19 disease is not known. Therefore, we detail the demographic, clinical, radiological, laboratory results, treatment and outcomes of 22 consecutive COVID-19-positive (confirmed by reverse-transcriptase polymerase chain reaction (RT-PCR)) stroke patients diagnosed during the lockdown period 23rd March to 1st May 2020 inclusive at a tertiary London neuroscience centre. The mean age is 70.3 ± 2.2 years (range 49–83 years old, 14 (64%) males and 8 (36%) females). We classified these patients into (i) hospital acquired COVID-19; those who developed COVID-19 in the hospital while being treated for stroke, (ii) community acquired COVID-19; patients who had COVID-19 symptoms in the community shortly before attending the hospital with stroke and (iii) stroke as a direct complication of COVID-19; patients who were treated in intensive care with obvious prothrombotic state.

Table 1 cases 1–5 are hospital acquired COVID-19, this category of patients has not been described before. These were the patients being treated for stroke in mid-March 2020, when wearing personal protective equipment (PPE) was not recommended for staff looking after non-COVID-19 patients. In addition, relative visiting rules were not restricted. Cases 2–5 had high poor functional status before hospital admission and high frailty score on admission. They presented with mild fever at the time of testing and normal chest X-ray. They received oxygen therapy by nasal canulae for their COVID-19 and did not require or proceed for intensive care input. Cases two and three were discharged home at similar level of function as before and the others deceased. It is interesting to note the two discharged patients had minimum elevation of high-sensitivity C-reactive protein (CRP). None of these patients had worsening of stroke symptoms.

Twelve community acquired COVID-19 patients (Cases 6–17) developed stroke within 72 h of showing COVID-19 symptoms. Ten patients presented with fever, six had also cough, three patients had severe hypoxia on admission (87% on 15 L O2 in case 7, 70% on 15 L O2 in case 16 and 89% on 15 L O2 in case 17). These three patients are care home residents, have high pre-admission mRS and frailty score. Cases 6–8, 10–12, 14–15 and 17 had confirmed large vessels stroke. Two cases (13 and 16) were clinically unstable on admission and diagnosed without brain imaging. Cases 6, 9–14 and 17 of ischaemic stroke patients with known symptom onset presented late (> 4.5 hr). Case nine had intraventricular haemorrhage due to a suspected arterio-venous malformation (AVM). We noted that the majority of the patients who died had high CRP. Patients who had hypoxia and abnormal chest X-ray at presentation except case 14, did not survive. Difficult to ascertain whether patients of community acquired COVID-19 developed stroke as a different disease process or as a result of COVID-19. The patients’ pre-morbid status and clinical findings in this group suggest that perhaps these patients developed stroke as an additional disease to their COVID-19 infection.

We report five cases (18–22) where patients had severe COVID-19 disease and developed (apart from case 22 which is a stroke mimic) multiorgan failure and large vessel stroke. These patients are middle age males with pre-admission mRS of zero and very low frailty score. Presenting

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Table 1  Demographic, clinical, radiological, laboratory findings, management and outcome of stroke patient who acquired COVID-19 at the hospital

| Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|--------|--------|--------|--------|--------|
| **Age/sex** | 75/M | 67/F | 83/F | 74/M | 81/F |
| **Ethnicity** | White | Black | White | White | White |
| **Past medical history** | None | Previous stroke, HTN, HL, T2DM | AF on warfarin, HTN, IHD, CCF | T2DM, IHD, CCF, AF, Non-Hodgkin’s lymphoma | Asthma, HTN, previous, stroke, AF |
| **Medications** | Bisoprolol, Ramipril, Levetiracetam, Lansoprazole, | Aspirin, atorvastatin, insulin, lansoprazole, levothyroxine, mirtazapine pregabalin, sitagliptin, quinine | Bisoprolol, Ramipril, bumetanide, simvastatin, warfarin | Amiodarone, Amiodpine, atorvastatin, bisoprolol, tamsulosin, sitagliptin, bumetanide, candesartan, Edoxaban | Amlodipine, Apixaban, Bisoprolol, Quetiapine, sertraline, salbutamol |
| **Pre-stroke mRS** | 1 | 4 | 4 | 5 | 4 |
| **Frailty score** | 2 | 6 | 6 | 8 | 6 |
| **COVID symptoms and duration** | Patient was about to be discharged home from 8 weeks inpatient stroke rehab developed fever at the beginning of lockdown | After 4 weeks inpatient stroke rehab developed fever at the beginning of lockdown | After 10 days inpatient stroke rehab developed mild dry cough at the beginning of lockdown | After 8 weeks inpatient rehab for stroke and infected prosthetic knee developed fever at the beginning of lockdown | After 8 weeks inpatient stroke rehab developed fever at the beginning of lockdown |
| **SatO₂/PaO₂ (ABG) at the time of diagnosis** | 98% RA | 96% RA | 96% RA | 96% RA | 96% RA |
| **Chest X-ray/CT at presentation** | Lung clear | Lung clear | Lung clear | Left lung mass and supradiaphragmatic lymph nodes | Lung clear |
| **COVID treatment** | NC O₂, antibiotics, complicated with chest abscess, required chest drain | NC O₂ | NC O₂, antibiotics | NC O₂ | NC O₂ |
| **Signs and symptoms of stroke** | 2-day history of expressive dysphasia and disorientation | Dysarthria, left sided weakness | Dysarthria with word finding difficulty | Vertigo | Left sided weakness and neglect |
| **Vascular territory** | Posterior circulation | Bilateral MCA | Left PCA | Right MCA | CT |
| **Imaging for diagnosis** | MRI | MRI | MRI | CT | MRI |
| **Imaging findings** | Left frontal haematoma with diffuse blood in convexity sulci bilaterally, cerebral Amyloid angiopathy | Left paramedian pontine infarct | Bilateral embolic infarct in the right insula, right posterior temporal lobe, left frontal operculum and left occipital lobe | Left PCA embolic infarct | Right parietal infarct |
| **Change in stroke after COVID-19** | No more bleed after COVID-19 | None | None | None | None |
| **Evidence of PE** | Large saddle PE | No CT-PA | No CT-PA | No PE on CT-PA | No CT-PA |
| **White-cell count-×10⁹/L** | 25.9↑↑ | 10.7 | 4.2 | 2.0↓ | 10.4 |
| **Lymphocytes count-×10⁹/L** | 0.8↓ | 1.4 | 0.6↓ | 0.7↓ | 0.4↓ |
| **Platelet count-×10⁹/L** | 214 | 179 | 156 | 180 | 235 |
| **High-sensitivity C reactive protein-mg/L** | 215↑↑ | 27↑ | 28↑ | 354↑↑ | 215↑↑ |
Table 1 (continued)

| Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|--------|--------|--------|--------|--------|
| Prothrombin time/INR | ↑1.4 | ↑1.2 | ↑1.2 | ↑2.5 | ↑1.4 |
| Activated partial thromboplastin time ratio | 1.01 | 1.00 | 0.96 | 1.01 | 0.87 |
| Fibrinogen-mg/dl | 5.3↑ | 4.4 | 2.5 | 10.9↑ | 4.0 |
| D-Dimer-ng/ml | − | − | − | − | 639↑ |
| Ferritin-µg/ml | − | − | − | 899↑ | 406↑ |
| Albumin-g/L | 27↓ | 28↓ | 31↓ | 20↓ | 24↓ |
| Clinical outcome | Palliated after confirmed PE, deceased at 28 days after confirmed COVID-19 (mRS 6) | Improved continue inpatient rehabilitation, then discharged home. (mRS 4) | Improved, continued inpatient rehabilitation, then discharged home. (mRS 4) | Deteriorated with ongoing suspected primary lung cancer, deceased 28 days after confirmed COVID-19 (mRS 6) | 3 weeks after Covid-19 positive, patient suffered a STEMI required PCI and coronary stenting. Cardiac arrest and deceased 7 days later (mRS 6) |

| Case 6 | Case 7 | Case 8 | Case 9 | Case 10 | Case 11 | Case 12 | Case 13 | Case 14 | Case 15 | Case 16 | Case 17 |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Age/sex | 75/M | 68/F | 75/M | 77/M | 83/F | 50/M | 76/F | 49/M | 74/M | 83/M | 78/F |
| Ethnicity | White | Asian | White | White | Black | Asian | Black | T2DM, CKD, HTN, IHD | T2DM, CKD, HTN, IHD | None | Asian |
| Past medical history | Terminal gastric cancer, IHD, AF, HTN, T2DM, CKD | Traumatic brain injury, PEG feed, Tracheostomy, T2DM, previous TIA | None | HTN, CKD | Dementia, T2 DM | | None | None | Previous stroke, HTN, T2DM, HL | | Dementia, Pulmonary TB in 2012 |
| Medications | Apixaban, Amiodarone, Bisoprolol, Furosemide, Mirtazapine, Omeprazole, LMWH, levothyroxine, Mirazapine, Ramipril, Metformin, Gliclazide, Empagliflozin, Atorvastatin, Donepezil | Amoxicillin, Citralopram, insulin, Levetiracetam, Metformin, Furosemide, Clopidogrel, Lansoprazole, Ramipril | None | Amlodipine, Ramipril, Metformin, Gliclazide, Empagliflozin, Atorvastatin, Donepezil | None | None | Furosemide, Tolterodine, Lisinopril, Indapamide, Prednisolone, Amlodipine, Aspirin, Simvastatin | Atorvastatin, Amlodipine, Clopidogrel, Lansoprazole, Metformin, Gliclazide, Perindopril, Doxorubicin | Warfarin, Clopidogrel, Amlodipine, Bisoprolol, Irbesartan, Etoricoxib, Metoprolol, Lisoprazole, Donepezil | Clopidogrel, Amlodipine, Furosemide, Levothyroxine, Metformin, Simvastatin, Bisoprolol |
| Admitted from | Home | Care home | Care home | Home | Home | Home | Home | Home | Home | Home | Care home |
| Pre-stroke mRS | 3 | 5 | 4 | 1 | 2 | 4 | 0 | 3 | 1 | 4 | 4 |
| Frailty score | 9 | 8 | 6 | 2 | 3 | 7 | 1 | 5 | 3 | 6 | 7 | 5 | 7 |
Table 1 (continued)

| Case 6 | Case 7 | Case 8 | Case 9 | Case 10 | Case 11 | Case 12 | Case 13 | Case 14 | Case 15 | Case 16 | Case 17 |
|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| COVID symptoms and duration before stroke | 24 h fever cough | 2-day history of fever | Low grade fever on 1 day after admission | Low grade fever dry cough 2 days after admission | 2-day history of fever, dizziness | 2-day history of low-grade fever, cough | 1-day history of shortness of breath | 3-day history of feeling unwell | 2-week history of fever, confirmed COVID-19 positive 10 days before | 2-day history of fever and cough | 24 h prior to admission fever, cough, hypoxia on admission |
| SatO$_2$/PaO$_2$ (ABG) on admission | 98% on RA | 87% on 15L | 98% on RA | 92% on RA | 92% on RA | 93% on 15 L O$_2$ | 96% on RA | 92% on RA | 70% on 15 L O$_2$ | 89% on RA |
| Chest X-ray/CT at presentation | Ground-glass airspace shadowing in the periphery | Mild peripheral infiltration | Ill-defined consolidation in the right mid zone | Bilateral multiple scattered air space opacities | Normal | Non-specific patchy bi-basal consolidation | Bilateral mid/lower zone patchy opacification | Patchy air space shadowing bilateral upper and mid zone | Bilateral lower zone patchy opacification | Diffuse bilateral fine opacification | Right cardiogenic angle opacity long standing |
| COVID treatment | NC O$_2$, antibiotics | NC O$_2$ | NC O$_2$ | NC O$_2$ | Intubation, Remdesivir, LMWH | NC O$_2$ | NC O$_2$ | NC O$_2$ | None | NC O$_2$ | NC O$_2$ | ICU non-invasive ventilator |
| Signs and symptoms of stroke | Aphasia, right side and left leg weakness NIHSS 15 | Reduced GCS, worsening right side weakness | Acute right arm weakness, NIHSS 8 | Dizziness and unsteady gait, NIHSS 4 | TIAs x 2 last 7 days, acute left facial droop, right sided weakness | Mild expressive aphasia, NIHSS 7 | Vertigo, unsteadiness, left facial numbness | Aphasia, right side weakness | Slurred speech, right side weakness, NIHSS 7 | Slurred speech, left sided weakness | Left sided weakness, with right eye deviation | Unresponsive, left sided weakness, NIHSS 32 |
| Stroke onset to presentation (hr) | 15 h | Unknown | 2 h, not thrombolyzed due to recent hip surgery | 12 h | 7 h | 6 h | 9 h | 8 h | 3 h not thrombolyzed, on warfarin INR 3.6 | 1 h not thrombolyzed as too unwell | 6 h |
| Vascular territory | Left MCA, right ACA | Left MCA | Bilateral MCA | – | Posterior circulation | Left MCA | Posterior circulation | Left MCA | Left MCA | Right MCA | Right MCA, right M1 clot |
| Imaging for diagnosis | CT | MRI | MRI | CT | CT | CT | Not stable for CT | CT/MRI | CT | Not stable for CT | CT |
| Case 6 | Case 7 | Case 8 | Case 9 | Case 10 | Case 11 | Case 12 | Case 13 | Case 14 | Case 15 | Case 16 | Case 17 |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| **Imaging findings** | Left MCA, right ACA infarct | Left MCA embolic infarct | Bilateral border zone between MCA PCA, left more than right | IVH possibly secondary to AVM | SVD, no large infarct | SVD, no large infarct | No acute change on CT, right VA dissection on CTA | n/a | Left uncus and internal capsule, and right corona radiata small infarct | Initial CT right MCA early ischemia, 24 h CT confirmed complete right MCA infarct | Clinical right MCA stroke | Complete right MCA infarct |
| Evidence of PE | No CTPA | No CTPA | No CTPA | No CTPA | No PE on CTPA | No CTPA | No CTPA | No CTPA | No CTPA | No CTPA | No CTPA |
| White-cell count x 10^9/L | 8.2 | 2.4↓ | 10.5↑ | 17.1↑ | 15.2↑ | 7.8 | 6.7 | 6.2 | 8.0 | 6.7 | 21.3↑ | 8.3 |
| Lymphocytes count x 10^9/L | 0.7↓ | 0.6↓ | 0.6↓ | 1.0↓ | 0.3↓ | 0.8↓ | 1.2 | 1.5 | 0.4↓ | 1.4 | 1.1 |
| Platelet count x 10^9/L | 185 | 224 | 302 | 281 | 264 | 223 | 149 | 259 | 698↑ | 155 | 446 | 342 |
| High-sensitivity C reactive protein-mg/L | 151↑ | 134↑ | 84↑ | 61↑ | 318↑↑ | 59↑ | 12↑ | 136↑ | 3 | 83↑ | 418↑↑ | 12↑ |
| Prothrombin time/INR | 1.2↑ | 1.1 | 1.0 | 1.0 | 1.3↑ | 1.1 | 1.0 | 1.2 | 1.0 | 3.6↑ | – | 1.0 |
| activated partial thromboplastin time ratio | 0.96 | 1.27↑ | 0.94 | 0.89 | 1.23↑ | 0.83 | 0.89 | 1.01 | 1.26↑ | 1.34↑ | – | 1.00 |
| Fibrinogen-mg/dl | 5.9↑ | 6.3↑ | 4.9↑ | 2.7 | 7.8↑ | 5.2↑ | 2.4 | 7.4↑ | 8.4↑ | 5.1↑ | – | 4.9↑ |
| D-Dimer-ng/ml | – | – | 909↑ | – | 3210↑↑ | – | 94 | – | – | – | – | – |
| Ferritin-µg/ml | – | – | 603↑ | – | 3957↑ | – | 595↑ | – | – | – | – | 628↑ |
| Albumin-g/L | 33↓ | 24↓ | 19↓ | 35 | 17↓ | 32↓ | 36 | 30↓ | 24↓ | 29↓ | – | 25↓ |
| **Clinical outcome** | Deceased on day 3, after 40 min rapid deterioration in hypoxia and fast AF (mRS 6) | Increased oxygen needs, Palliated deceased on day 4. (mRS 6) | Improved, discharged home (mRS 1) | Improved, discharged home on day 21 (mRS 6) | Improved, discharged home on day 3. (mRS 4) | Improved, transferred to local hospital for stroke rehabilitation, then discharged home. (mRS 1) | Palliated, deceased on day 2. (mRS 6) | Palliated, deceased on day 5. (mRS 6) | Palliated, deceased on day 12. after admission. (mRS 6) | Palliated, deceased on day 12. | Palliated, deceased on day 12. | Palliated, deceased on day 12. |
|                        | Case 18 | Case 19 | Case 20 | Case 21 | Case 22 |
|------------------------|---------|---------|---------|---------|---------|
| **Age/sex**            | 61/M    | 67/M    | 66/M    | 64/M    | 52/M    |
| **Ethnicity**          | Asian   | White   | Black   | White   | Asian   |
| **Past medical history** | HTN, HL | HTN, T2DM | None   | Glucose intolerance | Asthma |
| **Medications**        | Atorvastatin, amlodipine, clopidogrel | Amlodipine, Ramipril, Sitagliptin, Metformin | None | None | None |
| **Pre-stroke mRS**     | 0       | 0       | 0       | 0       | 0       |
| **Frailty score**      | 1       | 1       | 1       | 2       | 2       |
| **COVID symptoms and duration** | Developed cough while inpatient rehab after heart valve intervention | 3-day history of fever, cough, loss of taste | 5-day history of fever, mild diarrhoea, nausea, dry cough | 10-day history of cough and chest pain | 3-day history of dry cough, fever; 24 h shortness of breath |
| **SatO₂/PaO₂ (ABG) on admission** | 89% on 3L O₂ | 78% on RA/PaO₂ 7.31 kPa on ABG | 92% on 15L O₂ | 89% on 15L O₂/PaO₂ 7.89 on ABG | 60% on RA |
| **Chest X-ray/CT at presentation** | Widespread bilateral air space infiltrates with pulmonary oedema | Bilateral lower zone air space opacities. Obscuration of the left hemidiaphragm is indicative of left lower lobe consolidation | Extensive parenchymal lung disease essentially involving the entirety of both lungs, with a ground-glass and consolidative pattern | Scattered bilateral air space opacity | Bilateral lower lobe and peripheral predominant multiple opacities |
| **COVID treatment**    | Intubation, LMWH | Intubation, antibiotics, prophylactic LMWH | Intubation, steroid, antibiotics, LMWH | Intubation, steroid, LMWH | Intubation, steroid, LMWH |
| **Signs and symptoms of stroke** | Patient did not wake up after sedation wean | Left arm no movement | Reduced GCS, no limb movement | New fixed dilated pupils | Slow wake up after sedation wean |
| **Stroke onset to presentation** | Unknown | Unknown | Unknown | Unknown | Unknown |
| **Vascular territory** | Bilateral MCA | Bilateral MCA | Right MCA and post circulation | Right MCA | — |
| **Imaging for diagnosis** | CT | MRI | CT | CT | MRI |
| **Imaging findings**   | Bilateral MCA and thalamic hypodensity, mostly acute ischemia | MRI: Multiple acute border zone infarcts bilaterally in the anterior circulation and some in the posterior circulation occurring in the context of multifocal proximal intracranial arterial stenoses | CT | Right MCA and brainstem ischemia | MRI | Multifocal intraparenchymal cerebral haemorrhages and subarachnoid haemorrhage (haemorrhagic infarction), diffuse brain oedema | Diffuse haziness throughout the deep cerebral and cerebellar white matter, may be caused by the metabolic/physiological disturbance caused by critical illness |
| **Evidence of PE**     | No PE on CT-PA | No CT-PA | No PE on CTPA | Small PE on CT-PA | Distal small PE on CT-PA |
| **White-cell count- × 10⁹/L** | 19.8↑ | 14.9↑ | 38.4↑ | 18.8↑ | 11.4↑ |
| **Lymphocytes count- × 10⁹/L** | 0.4 ↓ | 0.2 ↓ | 0.3 ↓ | 0.5 ↓ | 0.4 ↓ |
| **Platelet count- × 10⁹/L** | 129 | 635↑ | 473↑ | 577↑ | 272 |
| **High-sensitivity C reactive protein-mg/L** | 364↑↑ | 335↑ | 345↑ | 388↑ | 338↑ |
| **Prothrombin time/INR** | 1.2↑ | 1.3↑ | 1.3↑ | 1.0 | 1.3↑ |
symptoms were typically of COVID-19. All shared chest radiographs abnormalities. They also had abnormally low oxygen saturation on admission and all needed intubation, ventilation and intensive care management. Apart from the stroke mimic case, all had high D-Dimer, ferritin and CRP. These cases share pro-thrombotic characteristics with most of the cases of Morassi et al. [2]. They all received full anticoagulation with low molecular weight heparin. Four out of these patients had CT pulmonary angiogram with no major pulmonary emboli (PE), suggesting PE may not be the major cause of their death. Further studies into this subpopulation are needed.

We included all COVID-19 stroke patients diagnosed within the period 23rd March and 1st May 2020. However, not all COVID-19 patients had brain scans and, therefore, the number of cases who were diagnosed with stroke due to severe COVID-19 disease may be underestimated. We present the management and outcome of a full spectrum of COVID-19-stroke patients in a tertiary centre. A pro-thrombotic state was found in severe COVID-19 patients, who did not do well, and stroke may be a late complication in these patients. Classifying COVID-19-stroke patients the way we did may help understand the disease and guide management.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical approval Consents have been obtained from patients, next of kin or legal representative. No identifiable data is presented.

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Table 1

| Case 18 | Case 19 | Case 20 | Case 21 | Case 22 |
|---------|---------|---------|---------|---------|
| activated partial thromboplastin time ratio | 2.81 | 6.31 | > 6000 | 141 |
| Fibrinogen-mg/dl | 1.11 | 1.77 | 4097 | 15 |
| D-Dimer-ng/ml | > 6000 | > 6000 | > 6000 | > 6000 |
| Ferritin-µg/ml | > 6000 | 1049 | 4491 | 1233 |
| Albumin-g/L | 15 | 14 | 14 | 15 |
| Clinical outcome | Improved, continue ward rehabilitation (mRS 4) | Renal failure, deceased on day 11 (mRS 6) | Renal failure, deceased on day 4 (mRS 6) | Renal failure, deceased on day 17 (mRS 6) | Improved, continue ward rehabilitation (mRS 4) |

Table 1 (continued)

| Case 18 | Case 19 | Case 20 | Case 21 | Case 22 |
|---------|---------|---------|---------|---------|
| ABG arterial blood gases, A PaO 2 partial pressure of oxygen, ALB albumin, ALT alanine transaminase, AST aspartate transaminase, BUN blood urea nitrogen, WBC white-cell count, INR international normalized ratio, mRS modified Rankin scale, NEURO neurological examination, PE pulmonary embolus, PCA posterior cerebral artery, Ph-ABC pH, Ph-AO 2 partial pressure of oxygen, PaCO 2, PaO 2, PCV packed-cell volume, T2DM type II diabetes mellitus, T2F T2DM complications, T2FH T2DM hypertension, T2FL T2DM hyperlipidaemia, T2FW T2DM hyperglycaemia |

The reference ranges are as follows: activated partial thromboplastin time ratio, albumin, 35–50 g/L; 0.85–1.15; D-dimer, 21–300 ng/ml; ferritin, 30–400 µg/ml; fibrinogen, 1.6–4.8 mg/dl; high-sensitivity C-reactive protein, 0–5 mg/L; lymphocyte count, 1.1–4.0 × 10^9/L; platelet count, 150–450 × 10^9/L; prothrombin time/INR ratio, 0.8–1.5; white-cell count, 4–11 × 10^9/L.