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SYSTEMATIC REVIEW

Renal artery infarction in the SARS-Cov-2 era: A systematic review of case reports

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Summary *Aim: Renal artery infarction (RI) is the presence of blood clot in the main renal artery or its branches causing complete or partial obstruction of the blood supply. Its etiology is either related with disorders of the renal vasculature or with cardiovascular diseases. Recently, the SARS-CoV-2 virus is an emerging cause of thromboembolic events and the incidence of RI is anticipated to increase after the pandemic.*
Methods: A systematic review based on COVID-19 associated RI was conducted. Protocol: A systematic review of the Medline/Pubmed and Scopus databases was conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (the PRISMA statement). Search strategy and information sources: A hand-search was performed using the terms "SARS-Cov-2" OR "COVID-19" AND "renal thrombosis" OR "renal infarction" OR "renal "thromboembolism". Eligibility criteria: all types of publications (case reports, case series, letters to the editor, short communications) were evaluated for relevance. Inclusion criteria were: confirmed SARS-Cov-2 infection irrespectively of the age, diagnosis of RI during or after the onset of viral infection, and exclusion of other potential causes of thromboembolic event except of SARS-Cov-2. Patients with renal transplantation were also considered. Study criteria selection: after checking for relevance based on the title and the abstract, the full texts of the selected papers were retrieved and were further evaluated. Duplicated and irrelevant cases were excluded. Any disagreement was resolved by consensus with the involvement of a third reviewer. Quality of studies: The assessment of the quality case reports was based on four different domains: selection, ascertainment, casualty and reporting. Each paper was classified as "Good", "Moderate" and "Poor" for any of the four domains. Data extractions: Crucial data for the conduct of the study were extracted including: age, sex, time from SARS-Cov-2 infection till RI development, medical history, previous or current antithrombotic protection or treatment, laterality and degree of obstruction, other sites of thromboembolism, treatment for thromboembolism and SARS-Cov-2 and final outcome. Data analysis: methods of descriptive statistics were implicated for analysis and presentation of the data.
Results: The systematic review retrieved 35 cases in 33 reports. In most cases, RI was diagnosed within a month from the SARS-Cov-2 infection albeit 17 out of 35 patients were receiving or had recently received thromboprophylaxis. Right, left, bilateral and allograft obstruction was diagnosed in 7, 15, 8 and 5 patients respectively. 17 cases experienced additional extrarenal thromboembolism primarily in aorta, spleen, brain and lower limbs. Low molecular weight heparins (LMWH) (usually 60-80 mg enoxaparine bid) was the primary treatment, followed by combinations of unfractionated heparin and salicylic acid, apixaban and rivaraxaban, warfarin, acenocoumarol or clopidogrel. Kidney replacement therapy was offered to five patients while invasive therapies with thrombus aspiration or catheter directed thrombolysis were performed in two. Regarding the outcomes, five of the patients died. The total renal function was preserved in 17 cases and renal impairment with or without hemodialysis was recorded in 5 patients, two of them having lost their kidney allografts. Limitations: The majority of included studies are of moderate quality. The results and the conclusions are based on case-reports only and crucial data are dissimilarly presented or missing through the relevant publications.
Conclusions: Thromboprophylaxis may not offer adequate protection against SARS-Cov-2 induced thrombosis. Most patients could be effectively treated with conservative measures, while in more severe cases aggressive treatment could be recommended.
Implications of key findings: Therapeutic doses of LMWH could be considered for protection against RI in SARS-Cov-2 cases. Interventional treatment could be offered in a minority of more severe cases after carful balancing the risks and benefits.

KEY WORDS: *Keywords: Renal; Artery infarction; Thromboembolism; SARS-Cov-2; COVID-19.*

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INTRODUCTION

Renal artery infarction (RI) describes the presence of blood clot in the main renal artery or its branches causing complete or partial obstruction of the blood supply. Its etiology is either related with intrinsic disorders of the renal vasculature or with cardiovascular disorders outside the kidney (1-2). The blood perfusion impairment results in renal injury and failure, partial or total, permanent or not, though the final outcome is primarily related with the prompt diagnosis and treatment (3-5).

The correct diagnosis of RI is a challenge for the physician. The disease may mimic the renal colic or other conditions such as urinary tract infection, acute abdomen, cardiac and pulmonary diseases, necessitating a multidisciplinary diagnostic work up (1-2, 6-8). Several case series are referred to RI management, mainly reflecting the experience and preferences of each group, but high-quality comparative series investigating the prognostic factors, the optimal diagnostic algorithm, the best treatment strategy and the role of prompt management in disease outcome are lacking. A number of different pharma-

ceutical regimens and interventional therapies have been tested in RI patients but with inconclusive results in terms of preservation of renal function (1-3, 6-10).

The new SARS-Cov-2 infection, the etiology of the COVID-19 pandemic outbreak may cause significant infection of the respiratory system and at the same time may affect multiple other organs through a prothrombotic and inflammatory effect involving the immune and vascular system albeit the mechanism of activation of the cascade of events leading to clot formation is still under investigation (11-13).

The incidence of RI is anticipated to increase after the SARS-CoV-2 pandemic. At present, the management of post COVID-19 RI is based on the experience accumulated before the pandemic onset and therefore contemporary clinical research might be beneficial. Attempting to add on the existing body of evidence we conducted a review of the literature exclusively with patients who developed RI during or after the infection with SARS-Cov-2. Emphasis is given in the history, the diagnostic workup, the laboratory findings and the treatment options. A discussion regarding the role of the new virus in the development of the thrombosis is also attempted. The optimal treatment of respiratory infection due to SARS-Cov-2 is beyond the scope of this review.

Materials and methods

Protocol

A systematic review of the Medline/ Pubmed and Scopus databases was conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (the PRISMA statement) (14).

Search strategy and information sources

The aforementioned databases were hand-searched until mid December 2022 using the terms "SARS-Cov-2" OR "COVID-19" AND "*renal thrombosis*" OR "*renal infarction*" OR "*renal "thromboembolism*".

Eligibility criteria

Based on the title and the abstract's content all types of publications (case reports, case series, letters to the editor, short communications) were independently evaluated for relevance by two of the authors of this manuscript (DK and GK). Inclusion criteria were: 1. confirmed SARS-Cov-2 infection irrespectively of the age, 2. diagnosis of RI during or after the onset of viral infection, and 3. exclusion of other potential causes of thromboembolic event except of SARS-Cov-2. Patients with renal transplantation or/and the co-existence of thromboembolic events outside the renal vascular system were also considered. Exclusion criteria were the absence of SARS-Cov-2 infection or of RI, the inadequate/poor presentation of the case, included the abstract-only cases and the non-English articles.

Study selection

After checking for relevance based on the title and the abstract, the full texts of the selected papers were retrieved and were further evaluated. Duplicated and irrelevant cases were excluded. Any disagreements were resolved by consensus with the involvement of a third reviewer (PF).

Data extraction

Three of the authors (DK, VK, PF) determined and extracted the crucial data for the conduct of the study: Age, sex, time from SARS-Cov-2 infection till RI development, medical history, previous or current antithrombotic protection or treatment, laterality and degree of obstruction, other sites of thromboembolism, treatment for thromboembolism and SARS-Cov-2 and final outcome.

Figure 1.
Prisma Flow diagram of selected cases.

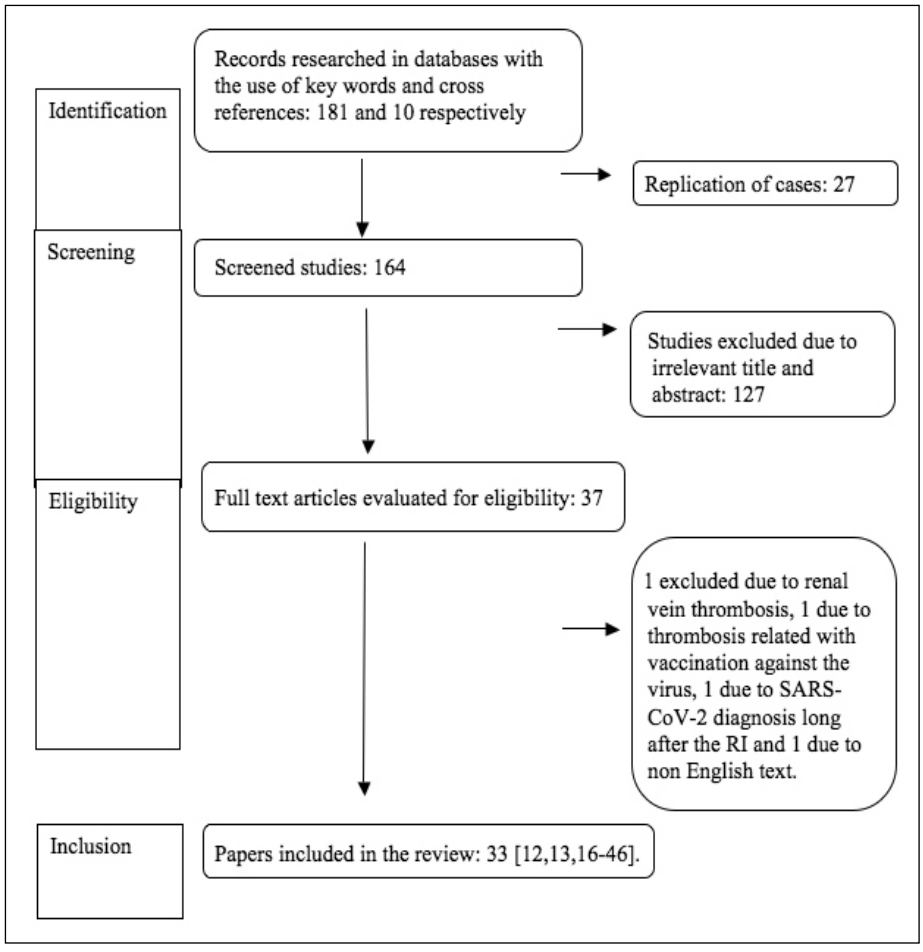

Table 1.
Assessment of risk of bias for each one of the included case reports for the domains of Selection, Ascertainment, Causality and Report. For each one of the four domains a classification in low (L), moderate (M) and high (H) risk is provided.

Author	Selection	Ascertainment	Causality	Report
Xu (16)	H	M	M	L
Acharya (17)	H	M	H	M
Mocerino (18)	H	L	M	L
Mukherjee (19)	H	L	L	L
Deshmukh (20)	H	H	H	M
Ramanathan (21)	H	M	L	M
Post (12)	M	M	M	L
	M	M	L	L
Añazco (22)	H	M	L	M
Lushina (23)	H	M	H	M
Kundal (13)	H	M	H	M
Besutti (24)	M	L	M	H
	M	M	H	H
Imoto (25)	H	M	M	M
Ammous (26)	H	L	M	L
Kenizou (27)	H	L	M	M
Webb (28)	H	H	M	L
Plouffe (29)	M	H	H	M
Singh (30)	H	H	H	M
Tantisattamo (31)	M	M	H	L
Belfort (32)	M	L	M	L
Topel (33)	H	M	H	M
Sethi (34)	H	M	L	M
Jentzsch (35)	H	M	L	L
Farias (36)	H	M	L	M
Al-Mashdali (37)	H	M	M	L
Mavraganis (38)	H	L	L	L
Jain (39)	H	L	M	M
Rigual (40)	H	M	M	L
Huang (41)	H	L	M	L
Mancini (42)	H	L	L	L
Gjonbalaj (43)	H	M	M	L
Brem (44)	H	L	L	M
Kourien (45)	H	M	H	M
Veterano (46)	H	M	H	L

Quality of studies
Two of the authors independently assessed the quality of each paper included in the study. *Murad et al*. (15) published a guide of assessment tools of a case report quality based on four different domains: Selection, Ascertainment, Causalty and Reporting. Considering that all the included papers were case report the studies were rated accordingly. Each paper was classified as "*Good*", "*Moderate*" and "*Poor*" for any of the four domains. Any disagreement in quality assessment was resolved with third part involvement (GV or IG).

Data analysis
Methods of descriptive statistics were applied for analysis and presentation of the demographics and clinical characteristics of the included population.

Results
A checklist of the included items in PRISMA systematic review is presented in supplementary Table 1. 33 papers with 35 RI cases were retrieved after the search of the databases (Figure 1). An overview of the quality of the papers is provided in Table 1 (12, 13, 16-46). Most of the case reports were assessed with moderate risk of bias. The overview of the retrieved papers is provided in Table 2.
The demographics and clinical characteristics with the relevant rates are provided in Table 3. All the patients except one were adults, the majority of whom were males in their sixth or seventh decade of their lives usually with a history of obesity, *diabetes mellitus* (DM) and/or smoking. Noteworthy, 17.6% of the patients had unremarkable medical history. In most of the cases the RI event was diagnosed within a month from the SARS-Cov-2 infection (mean 15.3 days). It is of interest that almost half of the cases (17/35) were receiving or had recently received thromboprophylaxis.
The most frequently used thromboprophylaxis was low

Table 2.
Overview of retrieved papers.

Author	Age (y)	Sex	Days after COVID-19 diagnosis/history	Antithrombotic/ anti-PLT Tx before RI	Laterality, & degree of obstruction	Other sites of thromboembolism	Tx for SARS-Cov-2	Tx for thromboembolism	Outcome
Xu 2020 (16)	46	M	27/DM, kidney–pancreas transplant	Intermittent enoxaparin 40 mg bid	Segmental artery, incomplete	No	Suppl O_2, azithromycin, prednisone, lopinavir/ritonavir, HCLQ cefuroxime	Enoxaparin 80 mg bid, at discharge apixaban 5 mg bid	Alive, RF ND
Acharya 2020 (17)	77	F	ND/hypothyreoidism, CAD, COPD, smoking, lung cancer, aortic aneurysm and bilateral renal stenting, recent embolization for leak	ASA	Bilateral incomplete	No	ND	ASA	Alive, RF ND
Mocerino 2020 (18)	69	F	ND/DM, AH, CAD	ASA, Clopidogrel	Left main incomplete	No	ND	IV heparine then apixaban	Preservation RF
Mukherjee 2020 (19)	71	M	9/unremarkable	Enoxaparin	Left superior	Ascending aorta	Suppl O_2, methylprednisolone, lopinavir/ritonavir, HCLQ	Stop enoxaparin, Heparine IV, Clopidogrel then apixaban + clopidogrel	Preservation RF
Deshmukh 2020 (20)	55	F	3/recent appendicitis	No	Bilateral left incomplete, right complete	Abdominal aorta	ND	ND	Multiorgan dysfunction, sepsis

Ramanathan 2020 (21)	54	M	11/obesity	No	Bilateral Segmental	Spleen	DXM, albuterol	Heparine 18U/Kgr/h then Apixaban 10 mg x2, shift to 5 mg x1	Preservation RF
Post 2020 (12)	62	M	9/AH, Henoch-Schonlein glomerulonephritis, kidney transplantation	Dalteparine 2500 U	Allograft segmental	No	Prednisone, high flow O_2	Dalteparin 15000U then Acenocoumarol	Slow improvement
	58	M	2/sleep apnea	Nadroparin 5700	Bilateral segmental	Bowel, lower limb	Non rebreathing mask O_2, mechanical ventilation	Heparin and Nadroparin + kidney replacement therapy bowel resection	ICU, rehab center
Añazco 2020 (22)	41	F	3/obesity, DM	No	Bilateral segmental massive left	No	O_2, DXM, ceftriaxone, ivermectin	Enoxaparin 60 mg bid, hemodialysis	Ventilation, AKI, death
Lushina 2020 (23)	84	M	0/AH, AF	No	Left upper segmental	Lung, brain, aortic arc	Intubation	Thrombectomy for brain thrombus	Died
Kundal 2020 (13)	39	F	ND/obesity, AH, contraceptives, patent foramen ovale	No	Right segmental	Aorta	ND	Apixaban (therapeutic dose)	Discharged home
Besutti 2020 (24)	54	M	9/former smoker, asthma, ulcerative colitis	No	Right main incomplete	Spleen	Lopinavir/ritonavir, HCLQ	LMWH 6,000 UI bid	Discharged home
	53	M	6/AH, mitral valve replacement	ASA	Left segmental	Spleen	Lopinavir/ritonavir, HCLQ, tocilizumab	LMWH 6,000 UI bid	Discharged home
Imoto 2020 (25)	64	M	15/gastric & duodenal ulcer	No	Bilateral	Brain, spleen	Favipiravir, ciclesonide, intubation, ECMO, meropenem, steroid, teicoplanin	Enoxaparin	Died
Ammous 2021 (26)	62	M	16/AH, asthma	LMWH prphylaxis (Stopped 2 days before RATE)	Left segmental	No	Suppl O_2	Heparin, then novel oral anticoagulant	Preservation RF
Kenizou 2021 (27)	78	M	9/obesity, pulmonary embolism, phlebitis	Rivaroxaban 10 mg	Right main complete	Left upper extremity, lung, brain, abdominal aorta	Cefotaxime, azithromycin	IV heparin, rivaroxaban stop, fogarty embolectomy for humeral thrombus	Ischemic stroke, GI bleeding, death
Webb 2021 (28)	49	M	27/CKI, kidney transplantation, rejection**	Enoxaparin 80 mg then 40 mg	Kidney Allograft, complete	No	Prednisone, high flow O_2, carbapenem	Enoxaparin 40 mg	Graft loss
Plouffe 2021 (29)	6	M	63 (suspected covid)/ unremarkable	No	Right segmental incomplete	No	Ceftriaxone	Aspirine 81 mg for 6 m	Full recovery
Singh 2021 (30)	32	M	30/unremarkable	No	Right main complete	No	Suppl O_2	Nephrectomy	Mucormycois, death
Tantisattamo 2021 (31)	33		9/obesity, DM, ESKD, kidney transplantation, post-transplant AKI	Clopidogrel, stop due to GI bleeding, heparin IV	Allograft segment, incomplete, microangiopathy	No	Norepinephrine, levofloxacin, ceftriaxone, intubation, remdesivir, DXM	IV Heparine, allograft nephrectomy	Cardiac arrest (survived), renal dialysis, new onset AF
Belfort 2021 (32)	28	M	3/DM, heart transplantation, dyslipidemia	No	Right Proximal segment incomplete	Descending thoracic aorta	Prednisone, ceftriaxone, azthriomycin, hydrocortisole	Enoxaparin, then warfarine	Improved
Topel 2021 (33)	55	M	28/smoking, AH	Enoxaparin stopped 14 d before RATE	Left segmental	Abdominal aorta, lower limb	Supp O_2, azithromycin, prednisole, favipravir	Thrombectomy for limb infarct, enoxaparine 0.8 mg, ASA 300 mg, pentoxyfylline 600 mg	Improving, palpable limb pulses
Sethi 2021 (34)	62	M	5/unremarkable	LMWH prophylaxis	Left segmental	No	Supp O_2, methylprednisolone, lopinavir/ritonavir	Renal dialysis, LMWH therapeutic dose	GI bleeding, normal RF
Jentzsch 2021 (35)	28	F	0/smoking, asthma, migraines	No	Left segmental	No	ND	Enoxaparin 1 mg/kg bid, then ASA81 mg + rivaroxaban 20 mg	Improved
Farias 2021 (36)	37	M	10/NA	No	Left main	No	ND	Enoxaparin 60 mg bid, then warfarin 5 mg/d	NA
Al-Mashdali 2021 (37)	43	M	-4/type B aortic dissection, deafness, smoking	No	Right main	Spleen	Suppl O_2	IV heparin, then warfarine 3.5 mg (target INR 2-3)	Chronic renal impairment, no dialysis
Mavraganis 2022 (38)	64	M	19/overweight	No	Left anterior segmental	Spleen, aorta	DXM, remdesivir, tocilizumab, ceftaroline, high flow nasal O_2	Enoxaparine 8000 bid + ASA 80 mg, then enoxaparine replaced by fondaparinux 7.5 mg	Improving
Jain 2022 (39)	62	M	8/unremarkable	No	Left main complete	Descending thoracic aorta	High flow nasal O_2, IV steroids, IV antibiotics	LMW heparin 80 mg bid followed by dabigatran 150 mg bid	Improving

Rigual 2022 (40)	53	M	10/cerebral infarction Tx with IV thrombolysis + thrombectomy	Enoxaparin 1 mg/kg, ASA 100 mg	Bilateral segmental	Spleen	Suppl O_2, methylprednisolone	1 mg enoxaparin/kg, ASA 100 mg, then ASA 300 mg	Rehab center
Huang 2022 (41)	62	M	19/DM	No	Left main & posterior complete	No	Suppl O_2, methylprednisolone, ceftriaxone, antiviral	Clopidogrel 75 mg, nadroparin 3800U/q12h then rivaroxaban	Preservation RF
Mancini 2022 (42)	43	M	3/mild stenosis of aortic valve, adrenal adenoma (non functioning)	No	Left upper, middle segmental	No	Piperacillin/ tazobactam	Enoxaparin 7000 UI bid, recur of thrombosis, then enoxaparin 8000 UI bid + ASA 100 mg	DMSA 28% relative renal function
Gjonbalaj 2022 (43)	5th decade	M	60/unremarkable	No	Left mid/distal segmental	No	ND	ASA 100 mg/d + heparin 25,000 UI/d thrombus aspiration + tirofiban 5 ml, stent, then ASA 100 mg+ Clopidogrel 75 mg	Full recovery
Brem 2022 (44)	59	M	14/DM	LMWH prophylaxis	Left	Spleen, lung, femoral artery thoracic aorta	Azithromycin, ceftriaxone, HCLQ	LMWH 60 mg bid, limb embolectomy	Limb amputation, RF preservation
Kourien 2022 (45)	32	M	30/unremarkable	Enoxaparin prophylaxis	Bilateral segmental	No	Remdesivir, methylprednisolone, tocilizumab, positive pressure O_2	Bilateral nephrectomy, combined antfungal agents	Permanent hemodialysis
Veterano 2022 (46)	56	F	30/Idiopathic CKD, kidney transplant, allograft dysfunction, obesity, heart failure, DM, AH, popliteal vein thrombosis	ASA, enoxaparin 20 mg, prophylaxis	Allograft main, quasi-complete	No	DXM, O_2 with nasal cannula	Catheter directed thrombolysis (alteplase, 5cc bolus, then 0.8 mg/h + IV heparine 500U/h) for 2 days + endoprosthesis, ASA 100 mg + enoxaparin 60 mg bid, then apixaban 5 mg bid	Allograft preservation, RF improved

NV: normal values, DM: diabetes mellitus, CAD: coronary artery disease, COPD: chronic obstructive pulmonary disease, RF: renal function, ND: not defined, AF: atrial fibrillation, AH: arterial hypertension, ICU: intensive care unit, GI: gastrointestinal, AKI: acute kidney injury CKI: chronic kidney injury, SC: subcutaneous, ASA: acetylsalicylic acid, ESKD: end stage kidney disease, LMWH: low molecular weight heparin, CKD: chronic kidney disease, HCLQ: Hydroxychloroquine, Suppl O_2: Supplementary oxygen, DXM: dexamethasone, ECMO: extracorporeal membrane oxygenation, IV intravenous.

dose *low molecular weight heparins* (LMWH), usually enoxaparin, followed by *amino-salicylic acid* (ASA), either as monotherapy or combined with heparin.

Of the 35 patients, five experienced allograft thrombosis. In the rest 30 patients, right, left and bilateral obstruction was diagnosed in 7, 15 and 8 patients respectively. In 17 cases, one or more organs outside the urinary tract were affected by the thromboembolic event with the aorta being most frequently involved (10 cases), followed by the spleen (8 cases), brain (3 cases), lower limb (3 cases), lung (3 cases) and elsewhere (2 cases).

All the patients were reported to complain about pain of sudden onset in the upper lateral abdominal quadrant and/or in the costovertebral angle ipsilateral to the affected kidney. The abdomen was tender in the affected side but the guarding reflex was rarely elicited. The WBC level is frequently elevated with the reported values being mostly above 15000 WBC/μL. Serum LDH and D-Dimers are almost uniformly above the normal range. Kidney injury is described in 12 cases while for 7 others reliable information were lacking.

The mainstay of the diagnosis was the *contrast-enhanced CT* (CECT) scan or preferably *CT angiography* (CTA) and in only one case *digital subtractive angiography* (DSA) as an adjuvant diagnostic modality to the CT scans. In two other cases the diagnosis of ischemia was established with renal biopsy. Massive or complete thromboembolism was revealed in eight patients. The rest of the patients had incomplete infarction of either the main artery or the segmental branches.

As it is shown in Table 3, the treatment for SARS-Cov-2 is reported for 29 patients and different combinations of drugs have been used. Steroids were most frequently delivered (51.4% of patients), followed by antibiotics (37.1%) and by antiviral treatment (31.4%). Hydroxychloroquine was delivered in 5 patients and monoclonal antibodies in 3. LMWH, mainly high dose enoxaparin (60-80 mg bid), was the primary treatment against thromboembolism in 19 cases, followed by therapeutic combinations containing unfractionated heparin (9 patients) and salicylic acid in dosages ranging from 81 to 300 mg/day. Upfront apixaban or other antithrombotic and anti-platelet agents (rivaraxaban, warfarin, acenocoumarol or clopidogrel) have also been delivered in RI patients.

Kidney replacement therapy was urgently offered to only five of the cases. Invasive therapies were performed in two patients. In one of them, with mid-distal segmental occlusion, aspiration and stent placement was performed and tirofiban was delivered to the thrombus site while the patient was under treatment with unfractionated heparin plus ASA. The patient experienced full recovery (43).

In another 56-year female with massive allograft thrombosis, history of chronic kidney disease, obesity, heart failure, diabetes type 2, arterial hypertention and lower limb

Table 3.
Patients' demographics and clinical characteristics.

Epidemiology	Age (range) years	52.1 (6-84)
	Male/female ratio	3.4/1
	Male %, Female %	77%, 23%
	Days for RI after COVID-19 diagnosis	15.3 d (0-63)*
History (for 34 pts)		
	Unremarkable (%)	6 (17.6)
	Transplantation (%)	6 (17.6)
Heart diseases	CAD (%)	2 (6)
	Chronic heart diseases (%)	4 (11.7)
	AF (%)	1 (3)
	AH (%)	8 (23.5)
	DM (%)	7 (20.5)
	Obesity/overweight (%)	7 (20.5)
	Smoking (%)	4 (11.7)
Pulmonary diseases	Asthma (%)	3 (8.8)
	COPD (%)	1 (3)
	Sleep apnea (%)	1 (3)
	Lung cancer (%)	1 (3)
Vascular diseases	Vasculitis/thromboembolism (%)	6 (17.7)
	Aorta aneurysm/dissection (%)	2 (6)
	Renal dysfunction (%) **	4 (11.7)
	Gastrointestinal diseases (%)	2 (6)
Others	Appendicitis (%)	1 (3)
	Migraines (%)	1 (3)
	Dyslipidemia (%)	1 (3)
	Deafness (%)	1 (3)
	Adrenal adenoma (%)	1 (3)
	Hypothyroidism (%)	1 (3)
	Contraceptive drug consumption (%)	1 (3)
Antithrombotic/anti-PLT Tx before RI (17 cases)		
	LMWH (%)	11 (31.4)
	IV Heparin (%)	1 (2.8)
	ASA (%)	5 (14.3)
	Clopidogrel (%)	2 (5.7)
Laterality		
	Right side (%)	7 (20)
	Left side (%)	15 (42.9)
	Bilateral (%)	8 (22.8)
	Allograft (%)	5 (14.3)
Degree of obstruction		
	Segmental artery (%)	25 (58)
	Main artery (%)	9 (21)
	The arterial site is not defined (%)	9 (21)
	Incomplete ***	9
	Complete ***	6
	Massive/quasi-complete ***	2
Other sites of thromboembolism		
	Aorta (%)	10 (28.6)
	Spleen (%)	8 (22.8)
	Lower limb (%)	3 (8.6)
	Lung (%)	3 (8.6)
	Brain (%)	3 (8.6)
	Upper limb (%)	1 (2.9)
	Bowel (%)	1 (2.9)
	No (%)	18 (51.4)
Tx for SARS-Cov-2		
Antibiotics (some pts received combinations) 13 pts (37.1%)	Azithromycin	6
	Cefuroxime	1
	Ceftriaxone/Cefotaxime	7
	Ceftaroline	1
	Levofloxacin	1
	Piperacillin/tazobactam	1
	Meropenem/carbapenem	2
	Teicoplanin	1
	ND antibiotics	1
Steroid agents (51.4%)	Prednisone/methylprednisolone/DXM	18
Antiviral 11 pts (31.4%)	Remdesivir	3
	Opinavir/ritonavir	5
	Favipiravir	2
	ND antiviral	1
HCLQ (14.3%)	HCLQ	5
Inhaler (5.7%)	Albuterol	1
	Ciclesonide	1
Mechanical ventilation/ intubation (11.4%)	Mechanical ventilation/intubation	4
	Ivermectin	1
Others	Tocilizumab	3
	ECMO	1
	Norepinephrine	1
O_2 treatment (45.7%)	Positive pressure	1
	ND (Supplementary)	10
	High flow	4
	Non-rebreathing	1
ND (20%)	ND	7
Overview of primary Tx for RI (%)	**Therapeutic agent in primary Tx for RI (no of pts)**	**Long term Tx or Tx after Discharge (no of pts)**
Single medical Tx 22 pts (62.9)	LMWH (19)	Apixaban (5)
Combined medical Tx 7 pts (20)	ASA (7)	ASA (5)
Surgical Tx 2 pts (5.7)	Heparin IV (9)	Clopidogrel (2)
ND 4 pts (11.4)	Clopidogrel (2)	Acenocoumarol (1)
	Apixaban (2)	Oral anticoagulant (1)
	ND Heparin (1)	Warfarine (2)
	Nephrectomy (2)	Rivaroxaban (2)
	Interventional/endovascular treatment (2)	Fondaparinux (1)
	ND (4)	Dabigatran (1)
Outcomes: no of pts	Dead: 5, Alive: 30	
	RF preservation: 8	
	Full recovery: 2	
	Improved /improving: 6	
	Multiorgan dysfunction/sepsis: 1	
	ICU: 2	
	Discharged home (no further info): 3	
	Discharged to rehabilitation center: 2	
	Renal dysfunction: 5	
	Loss of renal unit: 1	
	Cardiac arrest, AF: 1	
	GI bleeding: 2	

** In one case RI was diagnosed 4 days before the definite SARS-Cov-2 diagnosis.*
*** Irrelevant to history of transplantation.*
**** Rates are not displayed due to missing data.*

thrombosis, the treatment consisted of catheter directed thrombolysis with alteplase combined with IV heparin, endoprothesis placement, ASA and enoxaparin resulting in preservation of the transplant and improvement of renal function (46). Nephrectomy was necessitated in three other cases, one bilateral one unilateral and one for allograft removal.

Regarding the outcomes, five of the patients died. The total renal function was preserved or improving in 16 cases, while in another one the relative function was diminished to 28% in DMSA scans without affecting though the overall renal function. Renal impairment with or without hemodialysis was recorded in 5 patients, two of them having lost their kidney allografts. For 7 cases data regarding renal function outcome are inconclusive.

Discussion

The most frequent etiologic factor for RI of any cause is

atrial fibrillation (AF) encountered 25% to 75% of the patients (2, 8, 47). However, amongst patients with COVID-19-induced RI, AF is a rare occasion. The cytokine storm has been described in these patients predisposing to pro-inflammatory, prothrombotic and profibrotic effects induced by activated neutrophils and monocytes, as well as in causing damage to the endothelium (endothelitis) through the activation of angiotensin-converting enzyme-2 receptor. This cascade of events leads to activation and aggregation of factor VII, von Willebrand factor and fibrinogen and consequently to thrombin activation and fibrin clot formation and also in aggregation of platelets resulting in multiple thrombotic events (28, 32).

Several other factors predispose to the onset of the RI such as diabetes mellitus, arterial hypertension, hyperlipidemia, congestive heart failure, coronary artery disease, myocardial infarction, mitral valve disease and cerebrovascular disease (10, 47, 48). A relevant history has also been recorded in many patients of this review. Occasionally, in situ thrombosis may be iatrogenic in origin or traumatic (4, 49). History of a previous embolic event or thrombophilia with potential resistance of activated protein C and deficiency of protein S should also be examined (4, 5, 9).

Almost half of the COVID-19 related RI cases were receiving or had recently received thromboprophylaxis. It seems that low dose of LMWH or ASA do not offer adequate protection against RI so as to overcome the cytokine storm effect. The use of intermediate-dose enoxaparin in COVID-19-induced-hypoxia and before the onset of RI could be proposed as a measure to overcome the failure of thromboprophylaxis attributed to high levels of factor VII, von Willebrand factor and fibrinogen (28). Therefore based on the results of a randomized clinical trial *Spyropoulos et al.* recommended the administration of 1mg/kg bid of LMWH and 0.5 mg/kg bid for patients with clearance creatinine ≥ 30 and < 30 mL/min/1.73 m^2 respectively for hospitalized patients. The beneficial effect of the proposed dosages was evident in non ICU patients though (50).

The prompt diagnosis and treatment is the cornerstone of a favorable outcome for RI of any case. 90 minutes of normothermic ischemia can lead to irreversible damage of the renal parenchyma (3, 4), albeit this threshold is not always confirmed in clinical practice. Several groups have reported the preservation of renal function after many hours or even days after the onset of infarction (6, 51). In COVID-19-associated RI the delay in seeking for medical help cannot be evaluated because this piece of information is not reported in many of the included case reports but it seems that the degree of obstruction is more crucial than the delay in diagnosis. Three out of the five deaths of the review were recorded in the 8 patients with complete or massive infarction, indicating that the high degree of obstruction might be life threatening compared with the lower degree of RI.

The most frequently affected renal unit by COVID-19 was the left-sided, representing a finding that is poorly understood. In most case series with RI of any etiology both sides were almost equally infracted (2, 6, 9, 51). Three case series of the pre-COVID-19 era demonstrated a predominance of left RI which is a finding similar to that of the present review (47, 48, 52). Another paper from Korea though reported a higher incidence of right-sided RI (1). *Domanovits et al.* favor the hypothesis that the right renal artery has an acute angle of divergence with the aorta (48). In a more recent report it was revealed that the degrees of angulation were similar for both sides but the left orifice is larger than the right one and this fact may have influenced the laterality of RI (52). Apart from the dimensions of the orifice, it could be speculated that the length of renal arteries as well as the distance of the branching from the orifice may also play a role in the predominance of the left side.

Noteworthy *pulmonary embolism* (PE) among SARS-Cov-2 patients is a usual finding with an overall incidence of 16.5% (53). In the present review however PE was a rare finding among RI patients with the aorta and spleen being most frequently affected. If pulmonary infection was the triggering event of thromboembolism through the dissemination of infection and inflammation to the adjacent lung vessels it is anticipated that the incidence of PE would be much higher. However, the figure of three PE events of this review is too low to support this assumption. It has been shown that the virus may directly attack the respiratory system causing pneumonia, while the cardio-vascular system is affected either directly from the virus or indirectly through the blood stream with activation of cytokine storm and pro-inflammatory pathways. It seems that some vessels are more vulnerable than others perhaps due to endothelitis or to increased permeability of the endothelium enhancing the clot formation and platelet aggregation (54). This might explain the higher incidence of aortic and splenic infarctions compared to pulmonary or brain embolism. Moreover, in some patients the synchronous diagnosis of viral pneumonia and visceral infarction is indicative of the direct attack against the vascular system, while in others the long time interval (up to 63 days) between the COVID-19 pneumonia till the onset of infarction could be associated with an indirect assault (54). In most of the cases the WHO definition of long post-COVID-19 syndrome is met should the duration of RI symptoms lasts at least 2 months (55).

In the pre-SARS-CoV-2 era some authors advocate the DSA as the diagnostic gold standard. The sensitivity rates are as high as 100% but at a cost of increased invasiveness (3, 4). This modality has now been broadly replaced by *contrast enhanced CT* (CECT) imaging and *CT angiography* (CTA) showing single or multiple wedge-shaped filling defects of the renal parenchyma or global hypo-attenuation of the affected renal unit (compared with the healthy one). The blood clots may be also revealed in the vascular system. Infarcts involving greater than 50% of the renal parenchyma are considered global. Smaller single or multiples lesions (less than 50% of the renal unit) are classified as focal or multifocal respectively (56). The CECT/CTA sensitivity ranges from 80 to 97.3%, representing a rapid, non invasive, comprehensive and informative method for the diagnosis of RI and it should be performed as early as possible should renal infarction is suspected (2, 8, 48).

Nephrotoxicity due to radiopaque agents is well described and acute kidney injury may occur in the grounds of an already impaired renal function (57). However, the correct diagnosis cannot be established with other means and the

benefits from the administration of the contrast agent should be balanced against the potential risks. Therefore many authors proceeded to IVC administration in patients with renal impairment even at the risk of subsequent hemodialysis (12, 16, 20, 22, 27, 34, 37, 44, 46).

The treatment options against SARS-Cov-2 show a significant variability among the different medical centers. The combinations of regimens comprise mainly steroids plus broad spectrum antibiotics and usually antiviral treatment. Due to this variability the impact of anti-SARS-Cov-2 treatment on the natural history of thrombosis cannot not be reliably evaluated. Large scale studies with meticulous designed statistical analysis models might address the question whether some medications or combinations might play a preventive role against infarction.

Revascularization of RI is rarely attempted (1, 6, 8). In one of the biggest series comprising 438 RI of any cause the rate of thrombolysis with urokinase and embolectomy was as low as 4.5% and 0% respectively (2). However, it could be assumed that following a prompt diagnosis and perhaps in the settings of a massive or bilateral RI, endovascular surgery or thrombolytic management may be applied despite the risks of complications (3-5, 46, 48). In the present review, revascularization techniques were applied in one case with almost complete allograft obstruction and in another with a lesser degree of occlusion both with favorable results (43, 46).

Mortality rate after RI of any cause ranges from 0% to 23.4% (1-3, 7-9). The total number of 5 deaths in 35 patients with post COVID-19 RI corresponds to a rate of 14.3% which is reasonable for a severe disease burdened by the unfavorable prognosis of SARS-Cov-2. Perhaps the prompt diagnosis with modern CT-scanners, the close monitoring of the patients and the availability of new generation anti-coagulative agents may all have contributed to acceptable survival rates. Nevertheless, the broader use of higher dosages of thromboprophylaxis might further enhance the outcomes in post-COVID-19 renal infarction (28, 50).

This review has several limitations. As it is shown in table 2 the majority of included studies are of moderate quality.

The results and the conclusions are based only on case-reports and data are missing through the relevant publications. Any treatment of RI is based upon the preferences of the responsible physicians since therapeutic and follow up protocols differ among the medical centers. The outcomes are dissimilarly presented increasing the likelihood of bias. Therefore, a direct comparison of the studies or classification of the patients from different reports should be made with caution. Moreover, papers published in non English language and presentations in scientific meetings were not included in this review increasing the likelihood of missing data.

Conclusions

Thromboprophylaxis may not offer adequate protection against SARS-Cov-2 induced thrombosis. If RI is suspected the correct diagnosis is based on CECT/CTA scan and it should be performed as soon as possible, even in patients with renal impairment after careful balancing the risks and benefits. Most patients could be effectively treated with conservative measures, particularly with therapeutic-dose LMWH, while in more severe cases with massive and complete occlusion perhaps more aggressive treatment could be recommended. Large scale multicenter studies might address the role o SARS-Cov-2 treatment on infarction, as well as the optimal treatment option against thromboembolism.

References

1. Yun WS. Long-term follow-up results of acute renal embolism after anticoagulation therapy. Ann Vasc Surg. 2015; 29:491-5.

2. Oh YK, Yang CW, Kim Y-L, et al. Clinical Characteristics and Outcomes of Renal Infarction. Am J Kidney Dis. 2016; 67:243-250.

3. Piffaretti G, Riva F, Tozzi M, et al. Catheter-directed thrombolysis for acute renal artery thrombosis: report of 4 cases. Vasc Endovascular Surg. 2008; 42:375-9.

4. Blum U, Billmann P, Krause T, et al. Effect of local low-dose thrombolysis on clinical outcome in acute embolic renal artery occlusion. Radiology. 1993; 189:549-54.

5. Gasparini M, Hofmann R, Stoller M. Renal artery embolism: clinical features and therapeutic options. J Urol. 1992; 147:567-72.

6. Bourgault M, Grimbert P, Verret C, et al. Acute renal infarction: a case series. Clin J Am Soc Nephrol. 2013; 8:392-8.

7. Bolderman R , Oyen R, Verrijcken A, et al. Idiopathic Renal Infarction. Am J Med. 2006; 119:356.e9-12.

8. Hazanov N, Somin M, Attali M, et al. Acute renal embolism. Forty-four cases of renal infarction in patients with atrial fibrillation. Medicine (Baltimore). 2004; 83:292-299.

9. Korzets Z, Plotkin E, Bernheim J, et al. The clinical spectrum of acute renal infarction. Isr Med Assoc J. 2002; 4:781-4..

10. Lessman RK, Johnson SF, Coburn JW, et al. Renal artery embolism: clinical features and long-term follow-up of 17 cases. Ann Intern Med. 1978; 89:477-82.

11. Kappel C, Piticaru J, Jones G, et al. A case of possible Fournier's gangrene associated with proning in COVID-19 ARDS. Can J Anaesth. 2020; 67:1697-1698.

12. Post A, den Deurwaarder ESG, Bakker SJL, et al. Kidney Infarction in Patients With COVID-19. Am J Kidney Dis. 2020; 76:431-435.

13. Kundal SV, Emeasoba EU, Harris C, et al. Aortic thrombosis and renal infarction in a young female with patent foramen ovale and COVID-19 antibody. Clin Case Rep. 2020 2; 9:345-349.

14. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 2009; 6:e1000097..

15. Murad MH, Sultan S, Haffar S, et al. BMJ Evidence-Based Medicine. 2018; 23:60-63.

16. Xu JJ, Samaha D, Mondhe S, et al. Renal infarct in a COVID-19-positive kidney-pancreas transplant recipient. Am J Transplant. 2020; 20:3221-3224.

17. Acharya S, Anwar S, Siddiqui FS, et al. Renal artery thrombosis in COVID-19. IDCases. 2020; 22:e00968.

18. Mocerino R, Kumar N. Acute Abdominal Pain in a COVID-19 Patient. Kidney360. 2020 25; 1:584-585.

19. Mukherjee A, Ghosh R, Furment MM. Case Report: COVID-19 Associated Renal Infarction and Ascending Aortic Thrombosis. Am J Trop Med Hyg. 2020; 103:1989-1992.

20. Deshmukh SB, Upadhyay KM, Kulkarni A, et al. Renal Artery Thrombosis: A Post COVID-19 Sequel. J Adv Res Med. 2020; 7:22-24.

21. Ramanathan M, Chueng T, Fernandez E, et al. Concomitant renal and splenic infarction as a complication of COVID-19: a case report and literature review. Infez Med. 2020; 28:611-615.

22. Añazco PH, Balta FM, Córdova-Cueva L. Bilateral renal infarction in a patient with severe COVID-19 infection. J Bras Nefrol. 2021; 43:127-131.

23. Lushina N, Kuo JS, Shaikh HA. Pulmonary, Cerebral, and Renal Thromboembolic Disease in a Patient with COVID-19. Radiology. 2020; 296:E181-E183.

24. Besutti G, Bonacini R, Iotti V, et al. Abdominal Visceral Infarction in 3 Patients with COVID-19. Emerg Infect Dis. 2020; 26:1926-1928.

25. Imoto W, Kaga S, Noda T, et al. Coronavirus disease with multiple infarctions. QJM. 2020 1; 113:907-908.

26. Ammous A, Ghaffar MA, El-Charabaty E, et al. Renal infarction in COVID-19 patient. J Nephrol. 2021; 34:267-268.

27. Kenizou D, Perrin C, Harzallah I, et al. Multiple Arterial Thrombosis in a 78-Year-Old Patient: Catastrophic Thrombotic Syndrome in COVID-19. CJC Open. 2021; 3:198-200. .

28. Webb C, Davidson B, Jones ESW, et al. COVID-19-Associated Graft Loss From Renal Infarction in a Kidney Transplant Recipient. Kidney Int Rep. 2021; 6:1166-1169.

29. Plouffe B, Van Hooren T, Barton M, et al. Renal Infarcts-A Perplexing Case in the Middle of the COVID-19 Pandemic. Front Pediatr. 2021 14; 9:669453.

30. Singh T, Chaudhari R, Gupta A. Renal artery thrombosis and mucormycosis in a COVID-19 patient. Indian J Urol. 2021; 37:267-269.

31. Tantisattamo E, Dafoe DC, Ferrey AJ, et al. Kidney allograft infarction associated with transplant renal artery stenosis in a COVID-19 kidney transplant recipient. Clin Nephrol Case Stud. 2021 26; 9:93-104.

32. Belfort DSP, Marcondes-Braga FG, Mangini S, et al. Aortic and Renal Artery Thrombosis as the First Clinical Manifestation of COVID-19 in a Heart Transplant Recipient. Arq Bras Cardiol. 2021; 117:1045-7.

33. Topel C, Yıldırım C, Yavas MA, et al. Aortic floating thrombi with lower limb ischemia and renal infarct in COVID-19: A remote thromboembolic complication. Turk Kardiyol Dern Ars. 2021; 49:233-236.

34. Sethi S, Mehta S, Mahajan R. Coronavirus Disease 2019 Infection Presenting with Renal Infarction: A Rare Case Report. Saudi J Kidney Dis Transpl. 2021; 32:865-868.

35. Jentzsch MS, Hsueh L, Pallapati KJ, et al. Abdominal Pain Due to Renal Infarction: An Unexpected Presentation of COVID-19. R I Med J (2013). 2021; 104:16-19.

36. Farias LABG, Cruz EA, Silva AMHPD, et al. Renal infarction in a patient with Coronavirus Disease 2019: another rare thrombotic event. Rev Soc Bras Med Trop. 2021; 54:e0038-2021.

37. Al-Mashdali AF, Alwarqi AF, Elawad SM. Simultaneous renal infarction and splenic infarction as a possible initial manifestation of COVID-19: A case report. Clin Case Rep. 2021; 9:e04819.

38. Mavraganis G, Ioannou S, Kallianos A, et al. A COVID-19 Patient with Simultaneous Renal Infarct, Splenic Infarct and Aortic Thrombosis during the Severe Disease. Healthcare (Basel). 2022; 10:150.

39. Jain A, Bector G, Jain D, et al. Renal Artery Thrombosis with Renal Infarction Secondary to COVID-19 Infection: A Rare Presentation. Indian J Nephrol. 2022; 32:191-2.

40. Rigual R, Ruiz-Ares G, Rodriguez-Pardo J, et al. Concurrent Cerebral, Splenic, and Renal Infarction in a Patient With COVID-19 Infection. Neurologist. 2022; 27:143-6. .

41. Huang H, Lin C, Chen Y, et al. Renal artery thrombosis in SARS-CoV-2 infection: a case report. BMC Nephrol. 2022; 23:175.

42. Mancini M, Randazzo G, Piazza G, et al. Arterial Thrombotic Complications in COVID-19: A Case of Renal Infarction. Biomedicines. 2022; 10:2354.

43. Gjonbalaj N, Uka S, Olluri E, et al. Renal artery thrombosis as a long-term complication of COVID-19. Radiol Case Rep. 2022; 18:260-5.

44. Brem FL, Tayef TAA, Rasras H, et al. Concomitant renal and splenic infarctions in a COVID-19-patient with a catastrophic thrombotic syndrome. Radiol Case Rep. 2022; 17:4030-3.

45. Kurien AA, Srinivasaprasad ND, Valavan KT. Renal infarction due to COVID-19-associated renal mucormycosis. Kidney Int. 2022; 101:655..

46. Veterano C, Antunes I, Coelho A, et al. Endovascular Treatment of Renal Artery Thrombosis in Living-Donor Kidney Transplant Recipient With Severe COVID-19 Disease. J Endovasc Ther. 2022; 29:966-970.

47. Rhee H, Song SH, Won Lee D, et al. The significance of clinical features in the prognosis of acute renal infarction: single center experience. Clin Exp Nephrol. 2012; 16:611-6.

48. Domanovits H, Paulis M, Nikfardjam M, et al. Acute renal infarction. Clinical characteristics of 17 patients. Medicine (Baltimore). 1999; 78:386-394.

49. Singh O, Gupta SS, Sharma D, et al. Isolated renal artery thrombosis because of blunt trauma abdomen: report of a case with review of the literature. Urol Int. 2011; 86:233-8.

50. Spyropoulos AC, Goldin M, Giannis D, et al. HEP-COVID Investigators. Efficacy and Safety of Therapeutic-Dose Heparin vs Standard Prophylactic or Intermediate-Dose Heparins for Thromboprophylaxis in High-risk Hospitalized Patients With COVID-19: The HEP-COVID Randomized Clinical Trial. JAMA Intern Med. 2021; 181:1612-20.

51. C-W Huang, M-J Lee, C-Y Hsu, et al. Clinical outcomes associated with anti-coagulant therapy in patients with renal infarction. QJM. 2018; 111:867-73.

52. Kagaya S, Ojima Y, Aoki S, et al. The size of the renal artery orifice contributes to laterality of acute renal infarction. Clin Exp Nephrol. 2018; 22:1128-32.

53. Suh YJ, Hong H, Ohana M, et al. Pulmonary Embolism and Deep Vein Thrombosis in COVID-19: A Systematic Review and Meta-Analysis. Radiology. 2021; 298:E70-E80.

54. Evans PC, Rainger GE, Mason JC, et al. Endothelial dysfunction in COVID-19: a position paper of the ESC Working Group for

Atherosclerosis and Vascular Biology, and the ESC Council of Basic Cardiovascular Science. Cardiovasc Res. 2020; 116:2177-84.

55. Soriano JB, Murthy S, Marshall JC, et al. WHO Clinical Case Definition Working Group on Post-COVID-19 Condition. A clinical case definition of post-COVID-19 condition by a Delphi consensus. Lancet Infect Dis. 2022; 22:e102-7.

56. Suzer O, Shirkhoda A, Jafri SZ, et al. CT features of renal infarction. Eur J Radiol. 2002; 44:59-64.

57. Obed M, Gabriel MM, Dumann E, et al. Risk of acute kidney injury after contrast-enhanced computerized tomography: a systematic review and meta-analysis of 21 propensity score-matched cohort studies. Eur Radiol. 2022; 32:8432-42.

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