Development of Wunderlich Syndrome following a Russell's viper bite

Development of Wunderlich Syndrome following a Russell's viper bite

Subramanian Senthilkumaran[1]*, Stephen W. Miller[2]*, Harry F. Williams[3], Ravi Savania[4], Ponniah Thirumalaikolundusubramanian[5], Ketan Patel[6] and Sakthivel Vaiyapuri[4§]

[1]Manian Medical Centre, Erode, Tamil Nadu, India

[2]The Poison Control Center, Children's Hospital of Philadelphia, USA

[3]Toxiven Biotech Private Limited, Coimbatore, Tamil Nadu, India

[4]School of Pharmacy, University of Reading, Reading, UK

[5]Trichy SRM Medical College Hospital & Research Centre, Trichy, Tamil Nadu, India

[6]School of Biological Sciences, University of Reading, Reading, UK

*These authors contributed equally.

[§]Correspondence to: s.vaiyapuri@reading.ac.uk

Abstract

Snakebite envenomation is a high priority neglected tropical disease that predominantly affects rural communities living in developing countries. Due to myriad of complications including coagulopathies, neurotoxicity, nephrotoxicity and local tissue destruction, treating snakebite victims is a major challenge for clinicians. Russell's viper (*Daboia russelii*) is one of the 'Big Four' venomous snakes in India, and it is responsible for the most snakebite-induced deaths and disabilities. Acute kidney injury occurs frequently following Russell's viper bites and it is a critical factor contributing to disabilities, deaths and excessive treatment costs. In addition to commonly observed envenomation effects, Russell's viper bites induce some rare complications such as priapism, sialolithiasis and splenic rupture. Here, we report a case of Wunderlich syndrome that developed in a 22-year-old male following a Russell's viper bite. The patient displayed severe coagulopathies, abdominal tenderness, and hypotension. Notably, a peri-nephric haematoma was identified through ultrasound and computerised tomographic imaging. The haemorrhage was successfully treated using angioembolisation, and the patient recovered without any difficulties. Although a clinical condition such as this is rare, it is important to create awareness among treating clinicians about its occurrence, diagnosis and clinical management.

Key words: Snakebite envenomation; Wunderlich syndrome; Russell's viper; per-nephric haematoma; acute kidney injury.

1. Introduction

Snakebite envenomation (SBE) results in as many as 150,000 deaths and around 500,000 permanent disabilities annually worldwide [1, 2]. In India alone, around 58,000 deaths occur every year due to SBE [3]. Russell's viper is one of the 'Big Four' venomous snakes in India and is responsible for the majority of SBE incidents and associated deaths, disabilities and socioeconomic ramifications in India [4-6]. The bites from Russell's viper are known to induce local inflammation, tissue damage, coagulopathies often resulting in haemorrhage, neurotoxicity and nephrotoxicity [7-9]. Notably, the development of acute kidney injury (AKI) following Russell's viper bites is common and it often necessitates expensive renal replacement therapy [10, 11]. Russell's viper bites are also known to induce several rare envenomation effects such as priapism [12], splenic rupture due to excessive haemorrhage [13] and sialolithiasis (development of calculi in salivary glands) [14] among others. Hence, it is important to promptly diagnose and treat such rare complications as they could lead to serious consequences. Wunderlich syndrome (WS) is a rare clinical complication that represents a peri-nephric or peri-renal haemorrhage that spontaneously (non-traumatic) develops in the renal subcapsular space. The typical clinical symptoms of WS include sudden onset of flank pain, palpable flank mass,

and hypovolemic shock [15]. Failure to diagnose and promptly treat WS may result in serious morbidities or death [16]. The most common non-traumatic causes of WS include benign and malignant tumours, vasculopathy and infections [17]. To the best of our knowledge only one case of spontaneous peri-nephric haematoma following SBE has been reported previously [18]. We report a case of WS that developed in a 22-year-old male following a Russell's viper (*Daboia russelii*) bite in South India. This patient was successfully treated with angioembolisation without any further complications. This case report will inform clinicians that WS after SBE (specifically Russell's viper) is a possibility and aid in successful diagnosis and clinical management.

2. Case Report

A 22-year-old male was bitten by a snake on his right ankle while working on a farm. The snake was immediately killed, and it was identified as a Russell's viper by a herpetologist (**Figure 1A**). The patient was taken to a local hospital within 30 minutes of the bite, and he displayed severe local pain, swelling and gum bleeding. His 20-minute whole blood clotting time (WBCT) was prolonged. Due to the unavailability of antivenom in the hospital, he was transferred to another local hospital within two hours (from the bite) where he was administered with 80 mL polyvalent antivenom produced against the 'Big Four' snakes [Russell's viper, cobra (*Naja naja*), krait (*Bungarus caeruleus*) and saw-scaled viper (*Echis carinatus*)] of India (Bharat Serums and Vaccines, India). His complications were managed conservatively in the second hospital, however, he still displayed prolonged WBCT, developed haematuria and sub-conjunctival haemorrhage (**Figure 1B**). Therefore, he received another 200 mL of antivenom over the next 36 hours. On the third day of admission (72 hours following the bite), he developed diffuse, severe abdominal pain, as well as nausea and vomiting. He was initially managed conservatively (using anti-emetic drugs and fluids) for around four hours. However, later he became hypotensive with decreased urine output. Hence, he was transferred to the Emergency Department for intensive care management approximately 80 hours following the bite.

There was no history of any trauma or significant medical, surgical or familial factors of any health conditions for the patient. Upon examination, he was conscious but in severe pain around the bite site and abdominal region. He was pale with cold and sweaty extremities. His blood pressure was 70/40 mm Hg, and the pulse rate was 116 beats/min. Abdominal examination revealed fullness in the right lumbar and iliac regions with severe tenderness and guarding. The baseline laboratory investigations upon admission showed a haemoglobin level of 6.5 g/dL, total leukocyte count of 22,000/µL, platelet count of 120,000/µL, blood urea of 64 mg/dL, and creatinine of 1.4 mg/dL (**Table 1**). His coagulation profile was significantly altered with a prolonged prothrombin time (PT), activated partial thromboplastin time (aPTT) and increased international normalised ratio (INR) of clotting. Additionally, the fibrin degradation products and D-dimer (14.68 mg/dL) levels were elevated while the fibrinogen level was decreased (101.4 gm/dL) (**Table 1**). The levels of all the electrolytes such as sodium, potassium, chloride and bicarbonate were normal. However, serum creatinine kinase level was increased to 216 U/L (normal: 24 - 195). His liver function tests revealed increased bilirubin (direct, indirect and total) and serum glutamic oxaloacetic transaminase (SGOT) levels although all the other parameters were normal. The possibility of macroangiopathic haemolytic anaemia (MAHA) was ruled out using peripheral smear of blood which appears to be normal. Similarly, thrombotic microangiopathy was not found in this patient. Haemoglobinuria and myoglobinuria were also absent. His abdominal ultrasound imaging revealed a hypo-echoic collection around the upper pole of the right kidney indicating a haematoma (**Figure 1C**). A renal doppler analysis was conducted to rule out any arteriovenous fistulae as a cause for blood collection. A non-contrast computerised tomographic (CT) scan of the abdomen revealed a large peri-nephric hyper-dense collection in the right kidney extending into the retroperitoneum [45-50 Hounsfield units (HU)] (**Figure 1D and 1E**). The urology experts were consulted, and they advised conservative management with close observation since the patient displayed signs of venom-induced consumption coagulopathy. He was resuscitated according to the standard protocols and transfused with four units of packed red cells and four units of fresh frozen plasma. Twelve hours later (92 hours after bite), he experienced constant, dull pain in the right flank with tachycardia, hypotension and oliguria. His haemoglobin level was decreased from 9.0 g/dL after transfusion of red cells to 7.5 g/dL with an international normalised ratio (INR) of clotting value of 1.6 and platelet count of

110,000/μL and creatinine level of 2.1 mg/dL (**Table 2**). Haemoglobinuria and myoglobinuria were absent.

Despite all the above management approaches, the patient's condition continued to deteriorate, and repeat CT imaging revealed that the peri-nephric haematoma had expanded, and bleeding had extended into the retroperitoneal cavity. Following careful review of the patient's status and available imaging, a decision was made to perform an emergency selective coil angioembolisation of a haemorrhagic branch of the inferior pole renal artery (**Figure 1F**). The procedure was performed via the right femoral artery with particles of 500-700 microns and fibered micro-coils to effectively control haemorrhage while preserving nephrons. Upon completion of the procedure, an angiogram confirmed complete occlusion of the embolised arteries. The patient's haemodynamic status and haemoglobin levels were subsequently improved.

The unremarkable results of the anti-neutrophil cytoplasmic antibody, perinuclear anti-neutrophil cytoplasmic antibody, erythrocyte sedimentation rate, C-reactive protein, anti-DNA antibody, extractable nuclear antigen (ENA) panel screening, anti-phospholipid antibodies, anti-nuclear antibody and rheumatoid factor tests excluded the possibility of any non-snakebite related causes of WS. He was discharged 10 days after admission to our hospital. Weekly follow up ultrasound scans revealed stabilisation in size of the haematoma, however, by the third week the lesion began to contract. Follow up ultrasound scan three months later revealed complete resolution of the haematoma with a normal-sized right kidney and no evidence of malignancies.

3. Discussion

WS is a life-threatening condition and most often it occurs due to benign or malignant neoplasms, and vasculopathy in renal tissues. It is characterised by acute development of spontaneous renal haemorrhage into the subcapsular and perirenal spaces [15]. Angiomyolipoma and renal cell carcinoma are common causes as well as vascular diseases such as polyarteritis nodosa, infections and other less common aetiologies [17]. In these conditions, compromised blood vessels may spontaneously rupture and bleed into the peri-nephric, subcapsular space [19]. Lenk's triad, described as acute flank or abdominal pain, palpable abdominal mass and hypovolemic shock is present in around a quarter of patients with WS [15, 20]. The diagnosis of WS is normally based on clinical presentation and the use of imaging tools to detect the presence of haematoma. Ultrasound scan may be the initial modality utilised to detect the lesion, however, CT and magnetic resonance imaging (MRI) are typically very sensitive in the diagnosis of haematoma [21]. The treatment of WS depends on the size and severity of the lesion. Conservative management including observation may be recommended for uncomplicated, small lesions. Larger haematomas and those with higher risk of haemorrhage are medical emergencies and they may be treated with embolisation or surgical management with either full or partial nephrectomy [22].

The development of AKI after SBE with corresponding elevations in creatinine and blood urea nitrogen (BUN) is commonly reported in the literature, although peri-nephric haematoma following SBE is a rare phenomenon [23, 24]. As stated above, WS presents with sudden spontaneous renal haemorrhage into the subcapsular and perirenal space with flank pain and hypovolemic shock due to non-traumatic causes [15], features that are not commonly found in SBE victims. A previous report described that a 34-year-old male patient bitten by a Russell's viper developed AKI and subsequently, a peri-renal haematoma [18]. This patient was bitten on the foot and developed oliguria, hypotension and multiple coagulopathies. On the eighth day of hospitalisation, the patient developed abdominal tenderness, hypotension and a peri-renal haematoma was discovered using ultrasound scan. Despite intensive resuscitative therapy which included transfusion of platelets and fresh frozen plasma, the patient died 10 days after the bite. An observational study of AKI caused by SBE conducted in Benin reported that 6% of the cases developed renal capsular haematomas [25]. A study that reviewed 92 cases of WS in Tamil Nadu, India from 2016 through 2018 did not find SBE as a potential aetiology for WS [21].

In the present case, none of the common aetiologies for WS were discovered. It is likely that this complication was developed directly or indirectly through the toxic effects of the Russell's viper venom. The venom of Russell's viper is known to contain many toxic components that can alter haemostasis and cause bleeding and/or clotting complications. Snake venom metalloproteases (SVMP), the most abundant toxin family in their venom, possess fibrinogenolytic as well as other coagulopathic effects [26]. Factor X activator (RVV-X) from Russell's viper venom is a well-known SVMP that activates factor X, in turn cleaving factor II (prothrombin) to yield the active form of thrombin in coagulation cascades [27]. Some SVMPs can also activate prothrombin and inhibit platelet function. SVMPs also degrade basement membrane components in blood vessels leading to endothelial dysfunction and haemorrhage [28]. The cleavage and release of native proteins and fragments from the extracellular matrix may lead to increased vascular permeability, stimulation of the functions of matrix metalloproteases, and serve to amplify the immune response to the initial damage [28, 29]. Damage associated molecular patterns (DAMPS) contribute to further inflammation in the affected areas. Snake venom serine proteases (SVSP) are present in many viper venoms, and indeed, a factor V activator (RVV-V) [30] and a thrombin-like serine protease (Russelobin) have been isolated from Russell's viper venom [31]. Some SVSPs may activate protein C which ultimately inactivates factor Va and factor VIIIa. This promotes negative feedback regulation of the coagulation cascades, which will ultimately lead to bleeding complications [32]. Together with enzymatic and non-enzymatic mechanisms, venom phospholipase A_2 (PLA_2) may inhibit the production of activated factor X by interfering with the tenase complex [33]. Clinically significant bleeding is commonly observed in victims following Russell's viper bites [34]. We have also previously reported excessive bleeding and subsequent splenic rupture in a Russell's viper bite victim [13]. Due to his age and healthy conditions, the rupture of pre-existing renal artery aneurysm may not be a cause for WS although we cannot completely rule out this possibility. Such rare and abnormal condition was not apparent in angiogram.

While the exact pathophysiological mechanisms underlying the development of WS in this case are unknown, there are several possibilities that may explain why this patient has developed the peri-nephric haematoma. The kidneys are highly vascular organs, and they receive approximately 1L of blood flow per minute which equates to 20% of resting cardiac output. The kidneys are thus exposed to a high circulating volume of venom toxins as they travel throughout the vasculature. One possibility is that these toxins may have caused sufficient vascular damage which resulted in haemorrhaging in this region of the kidney and resulted in the development of peri-nephric haematoma. Another possibility is that the area of the renal polar artery which developed the haematoma may have had a previously undetected defect which predisposed the vessel to further injury upon subsequent exposure to venom toxins. Although this patient did have laboratory evidence of AKI, it remains unclear if SBE-induced AKI increases the risk of WS as so few cases exist. Similarly to the previous case report [18], this patient also presented with signs and symptoms of systemic coagulopathy such as gingival and sub-conjunctival bleeding and AKI. Although AKI with tubular necrosis and interstitial nephritis have been reported following SBE in the past, peri-nephric haematoma or WS is rarely encountered [35]. Physicians treating SBE should be aware that any patient that presents with flank pain, even if the symptoms are delayed by multiple days following SBE, may require additional diagnostic investigations for this potentially life-threatening complication.

4. References

1. Kasturiratne A, Wickremasinghe AR, de Silva N, Gunawardena NK, Pathmeswaran A, Premaratna R, et al. The global burden of snakebite: a literature analysis and modelling based on regional estimates of envenoming and deaths. PLoS Med. 2008;5(11):e218. doi: 10.1371/journal.pmed.0050218. PubMed PMID: 18986210; PubMed Central PMCID: PMCPMC2577696.
2. Longbottom J, Shearer FM, Devine M, Alcoba G, Chappuis F, Weiss DJ, et al. Vulnerability to snakebite envenoming: a global mapping of hotspots. Lancet. 2018;392(10148):673-84. Epub 20180717. doi: 10.1016/s0140-6736(18)31224-8. PubMed PMID: 30017551; PubMed Central PMCID: PMCPMC6115328.

3. Suraweera W, Warrell D, Whitaker R, Menon G, Rodrigues R, Fu SH, et al. Trends in snakebite deaths in India from 2000 to 2019 in a nationally representative mortality study. eLife. 2020;9:e54076. doi: 10.7554/eLife.54076.
4. Simpson ID, Norris RL. Snakes of medical importance in India: is the concept of the "Big 4" still relevant and useful? Wilderness Environ Med. 2007;18(1):2-9. doi: 10.1580/06-weme-co-023r1.1. PubMed PMID: 17447706.
5. Vaiyapuri S, Vaiyapuri R, Ashokan R, Ramasamy K, Nattamaisundar K, Jeyaraj A, et al. Snakebite and its socio-economic impact on the rural population of Tamil Nadu, India. PLoS One. 2013;8(11):e80090. Epub 20131121. doi: 10.1371/journal.pone.0080090. PubMed PMID: 24278244; PubMed Central PMCID: PMCPMC3836953.
6. Samuel SP, Chinnaraju S, Williams HF, Pichamuthu E, Subharao M, Vaiyapuri M, et al. Venomous snakebites: Rapid action saves lives-A multifaceted community education programme increases awareness about snakes and snakebites among the rural population of Tamil Nadu, India. PLoS Negl Trop Dis. 2020;14(12):e0008911. Epub 20201231. doi: 10.1371/journal.pntd.0008911. PubMed PMID: 33382715; PubMed Central PMCID: PMCPMC7774832.
7. Gutiérrez JM, Calvete JJ, Habib AG, Harrison RA, Williams DJ, Warrell DA. Snakebite envenoming. Nat Rev Dis Primers. 2017;3:17063. Epub 20170914. doi: 10.1038/nrdp.2017.63. PubMed PMID: 28905944.
8. Bawaskar HS, Bawaskar PH. Diagnosis of envenomation by Russell's and Echis carinatus viper: A clinical study at rural Maharashtra state of India. J Family Med Prim Care. 2019;8(4):1386-90. doi: 10.4103/jfmpc.jfmpc_156_19. PubMed PMID: 31143726.
9. Williams HF, Layfield HJ, Vallance T, Patel K, Bicknell AB, Trim SA, et al. The Urgent Need to Develop Novel Strategies for the Diagnosis and Treatment of Snakebites. Toxins (Basel). 2019;11(6). Epub 20190620. doi: 10.3390/toxins11060363. PubMed PMID: 31226842; PubMed Central PMCID: PMCPMC6628419.
10. Mathew AJ, George J. Acute kidney injury in the tropics. Ann Saudi Med. 2011;31(5):451-6. doi: 10.4103/0256-4947.84620. PubMed PMID: 21911980; PubMed Central PMCID: PMCPMC3183677.
11. Senthilkumaran S, Patel K, Salim A, Vijayakumar P, Williams HF, Vaiyapuri R, et al. Neutrophil Gelatinase-Associated Lipocalin Acts as a Robust Early Diagnostic Marker for Renal Replacement Therapy in Patients with Russell's Viper Bite-Induced Acute Kidney Injuries. Toxins (Basel). 2021;13(11). Epub 20211112. doi: 10.3390/toxins13110797. PubMed PMID: 34822581; PubMed Central PMCID: PMCPMC8620021.
12. Senthilkumaran S, Williams HF, Patel K, Trim SA, Thirumalaikolundusubramanian P, Vaiyapuri S. Priapism following a juvenile Russell's viper bite: An unusual case report. PLoS Negl Trop Dis. 2021;15(3):e0009242. Epub 20210325. doi: 10.1371/journal.pntd.0009242. PubMed PMID: 33764978; PubMed Central PMCID: PMCPMC7993604.
13. Senthilkumaran S, Vijayakumar P, Savania R, Vaiyapuri R, Elangovan N, Patel K, et al. Splenic rupture and subsequent splenectomy in a young healthy victim following Russell's viper bite. Toxicon. 2021;204:9-13. Epub 20211028. doi: 10.1016/j.toxicon.2021.10.010. PubMed PMID: 34751135.
14. Arathisenthil SV, Senthilkumaran S, Vijayakumar P, Savania R, Williams HF, Elangovan N, et al. Rapid development of a salivary calculus in submandibular gland and its potential causes in a young victim following Russell's viper bite. Toxicon. 2022;206:85-9. Epub 20211231. doi: 10.1016/j.toxicon.2021.12.018. PubMed PMID: 34979198.
15. Katabathina VS, Katre R, Prasad SR, Surabhi VR, Shanbhogue AK, Sunnapwar A. Wunderlich syndrome: cross-sectional imaging review. J Comput Assist Tomogr. 2011;35(4):425-33. doi: 10.1097/RCT.0b013e3182203c5e. PubMed PMID: 21765296.
16. Medda M, Picozzi SC, Bozzini G, Carmignani L. Wunderlich's syndrome and hemorrhagic shock. J Emerg Trauma Shock. 2009;2(3):203-5. doi: 10.4103/0974-2700.55346. PubMed PMID: 20009313; PubMed Central PMCID: PMCPMC2776371.
17. Zhang JQ, Fielding JR, Zou KH. Etiology of spontaneous perirenal hemorrhage: a meta-analysis. J Urol. 2002;167(4):1593-6. doi: 10.1097/00005392-200204000-00006. PubMed PMID: 11912370.

18. Golay V, Roychowdhary A, Pandey R. Spontaneous peri-nephric hematoma in a patient with acute kidney injury following Russell's viper envenomation. Saudi J Kidney Dis Transpl. 2015;26(2):335-8. doi: 10.4103/1319-2442.152500. PubMed PMID: 25758885.
19. Muttarak M, Pattamapaspong N, Lojanapiwat B, Chaiwun B. Renal angiomyolipoma with bleeding. Biomed Imaging Interv J. 2007;3(4):e8. Epub 20071001. doi: 10.2349/biij.3.4.e8. PubMed PMID: 21614302; PubMed Central PMCID: PMCPMC3097681.
20. Parmar N, Langdon J, Kaliannan K, Mathur M, Guo Y, Mahalingam S. Wunderlich Syndrome: Wonder What It Is. Current Problems in Diagnostic Radiology. 2022;51(2):270-81. doi: https://doi.org/10.1067/j.cpradiol.2020.12.002.
21. Dhanapal V, Ramachandran R, Radhan P, Sambasivam B, Jeevanandham B, Jacob P. The Many Facets of Wunderlich Syndrome: A Multidetector Computed Tomography based Review. 2019;4:2565-4810. doi: 10.21276/ijcmsr.2019.4.1.22.
22. Flum AS, Hamoui N, Said MA, Yang XJ, Casalino DD, McGuire BB, et al. Update on the Diagnosis and Management of Renal Angiomyolipoma. J Urol. 2016;195(4 Pt 1):834-46. Epub 20151121. doi: 10.1016/j.juro.2015.07.126. PubMed PMID: 26612197.
23. Sitprija V. Snakebite nephropathy. Nephrology (Carlton). 2006;11(5):442-8. doi: 10.1111/j.1440-1797.2006.00599.x. PubMed PMID: 17014559.
24. Kanjanabuch T, Sitprija V. Snakebite nephrotoxicity in Asia. Semin Nephrol. 2008;28(4):363-72. doi: 10.1016/j.semnephrol.2008.04.005. PubMed PMID: 18620959.
25. Tchaou BA, de Tové KS, N'Vènonfon CFT, Mfin PK, Aguemon AR, Chobli M, et al. Acute kidney failure following severe viper envenomation: clinical, biological and ultrasonographic aspects. J Venom Anim Toxins Incl Trop Dis. 2020;26:e20200059. Epub 20201207. doi: 10.1590/1678-9199-jvatitd-2020-0059. PubMed PMID: 33335542; PubMed Central PMCID: PMCPMC7724935.
26. Slagboom J, Kool J, Harrison RA, Casewell NR. Haemotoxic snake venoms: their functional activity, impact on snakebite victims and pharmaceutical promise. Br J Haematol. 2017;177(6):947-59. Epub 20170224. doi: 10.1111/bjh.14591. PubMed PMID: 28233897; PubMed Central PMCID: PMCPMC5484289.
27. Tans G, Rosing J. Snake Venom Activators of Factor X: An Overview. Pathophysiology of Haemostasis and Thrombosis. 2001;31(3-6):225-33. doi: 10.1159/000048067.
28. Bickler PE. Amplification of Snake Venom Toxicity by Endogenous Signaling Pathways. Toxins (Basel). 2020;12(2). Epub 20200122. doi: 10.3390/toxins12020068. PubMed PMID: 31979014; PubMed Central PMCID: PMCPMC7076764.
29. Rucavado A, Nicolau CA, Escalante T, Kim J, Herrera C, Gutiérrez JM, et al. Viperid Envenomation Wound Exudate Contributes to Increased Vascular Permeability via a DAMPs/TLR-4 Mediated Pathway. Toxins. 2016;8(12):349. PubMed PMID: doi:10.3390/toxins8120349.
30. Yadav PK, Antonyraj CB, Basheer Ahamed SI, Srinivas S. Understanding Russell's viper venom factor V activator's substrate specificity by surface plasmon resonance and in-silico studies. PloS one. 2017;12(7):e0181216-e. doi: 10.1371/journal.pone.0181216. PubMed PMID: 28732041.
31. Mukherjee AK, Mackessy SP. Biochemical and pharmacological properties of a new thrombin-like serine protease (Russelobin) from the venom of Russell's Viper (Daboia russelii russelii) and assessment of its therapeutic potential. Biochim Biophys Acta. 2013;1830(6):3476-88. Epub 20130214. doi: 10.1016/j.bbagen.2013.02.007. PubMed PMID: 23416064.
32. Matsui T, Fujimura Y, Titani K. Snake venom proteases affecting hemostasis and thrombosis. Biochim Biophys Acta. 2000;1477(1-2):146-56. doi: 10.1016/s0167-4838(99)00268-x. PubMed PMID: 10708855.
33. Kini RM. Anticoagulant proteins from snake venoms: structure, function and mechanism. Biochem J. 2006;397(3):377-87. doi: 10.1042/bj20060302. PubMed PMID: 16831131; PubMed Central PMCID: PMCPMC1533313.
34. Mahasandana S, Rungruxsirivorn Y, Chantarangkul V. Clinical manifestations of bleeding following Russell's viper and Green pit viper bites in adults. Southeast Asian J Trop Med Public Health. 1980;11(2):285-93. PubMed PMID: 7434080.

35. Vikrant S, Jaryal A, Parashar A. Clinicopathological spectrum of snake bite-induced acute kidney injury from India. World J Nephrol. 2017;6(3):150-61. doi: 10.5527/wjn.v6.i3.150. PubMed PMID: 28540205; PubMed Central PMCID: PMCPMC5424437.

5. Tables

Table 1: **Laboratory results for the patient at the time of admission in the emergency department.**

Specimen	Investigation	Results	Unit	Normal range
	Haemoglobin	6.5	gms%	13.0 – 16.0
	Total RBC count	4.53	Millions/µL	4.00 – 5.00
	HCT	38.9	%	41.00 – 50.00
	MCV	85.9	fl	81.10 – 96.00
	MCH	29.1	pg	27.20 – 33.20
	MCHC	33.9	%	32 - 36
	Total WBC count	22.0	$x10^3$ Cells/µL	4.00 – 11.00
	Neutrophils	18.89	$x10^3$ Cells/µL	2.0 to 7.0
	Lymphocytes	3.01	$x10^3$ Cells/µL	1.0 to 3.0
	Monocytes	1.56	$x10^3$ Cells/µL	0.1 to 0.8
	Eosinophils	0.32	$x10^3$ Cells/µL	0.02 to 0.5
	Basophils	0.04	$x10^3$ Cells/µL	0.02 to 0.1
	Neutrophils	64.3	%	55 – 75
	Lymphocytes	21.8	%	15 – 30
	Eosinophils	2.3	%	1 - 5
	Monocytes	11.3	%	2 - 10
	Basophils	0.3	%	Up to 1
	Platelet Count	120	$x10^3$ Cells/µL	150 - 450
	MPV	9.8	fl	6.5 - 12.0
	PDW	10.5	fl	9.0 - 13.0
	Urea	64.0	mg/dL	15 - 40
	Creatinine	1.4	mg/dL	0.6 - 1.2

	Uric Acid	7.5	mg/dL	3.4 - 7.2
Serum	Uric acid	8.9	mg/dL	3.4 -7.2
Citrated plasma	Fibrinogen	101.4	gm/dL	150 - 400
Citrated plasma	D-Dimer	14.68	mg/dL	0 - 5
Serum	LDH	653	U/L	230 – 480
Citrated plasma	Prothrombin time	44.12	Seconds	11.6 (control)
Citrated plasma	INR	3.45	Ratio	
Citrated plasma	APTT	Prolonged	Seconds	26 - 40
Serum	Creatinine kinase	216	U/L	24 – 195
Serum	Bilirubin (total)	3.7	mg/dL	0.2 – 1.2
Serum	Bilirubin (direct)	0.85	mg/dL	0 – 0.2
Serum	Bilirubin (indirect)	2.85	mg/dL	0.2 – 0.9
Serum	SGOT	55	U/L	5 - 35

RBC, red blood cells; HCT, haematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular haemoglobin; MCHC, mean corpuscular haemoglobin concentration; WBC, white blood cells; MPV, mean platelet volume; PDW, platelet distribution width; LDH, lactate dehydrogenase; INR, International normalised ratio of clotting; APTT, activated partial thromboplastin time; SGOT, serum glutamic oxaloacetic transaminase.

Table 2: **Laboratory results for the patient after 12 hours of admission in the emergency department.**

Specimen	Investigation	Results	Unit	Normal range
	Haemoglobin	7.5	gms%	13.0 – 16.0
	Total RBC count	4.73	Millions/µL	4.00 – 5.00
	HCT	39.2	%	41.00 – 50.00
	MCV	82.9	fl	81.10 – 96.00
	MCH	29.8	pg	27.20 – 33.20
	MCHC	36.0	%	32 - 36
	Total WBC count	12.0	$x10^3$ Cells/µL	4.00 – 11.00
	Neutrophils	7.6	$x10^3$ Cells/µL	2.0 to 7.0
	Lymphocytes	4.01	$x10^3$ Cells/µL	1.0 to 3.0

	Monocytes	0.28	x10^3 Cells/µL	0.1 to 0.8
	Eosinophils	0.02	x10^3 Cells/µL	0.02 to 0.5
	Basophils	0.01	x10^3 Cells/µL	0.02 to 0.1
	Neutrophils	46.8	%	55 – 75
	Lymphocytes	41.1	%	15 – 30
	Eosinophils	0.8	%	1 - 5
	Monocytes	10.9	%	2 - 10
	Basophils	0.4	%	Up to 1
	Platelet Count	110	x10^3 Cells/µL	150 - 450
	MPV	10.2	fl	6.5 - 12.0
	PDW	10.2	fl	9.0 - 13.0
	Creatinine	2.1	mg/dL	0.6 - 1.2

RBC, red blood cells; HCT, haematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular haemoglobin; MCHC, mean corpuscular haemoglobin concentration; WBC, white blood cells; MPV, mean platelet volume; PDW, platelet distribution width.

6. Figure legend

Figure 1: **Development of conjunctival bleeding and peri-nephric haematoma in a patient following a Russell's viper bite**. **A**) the offending snake which was identified as a Russell's viper. **B**) the victim showing conjunctival bleeding on their left eye. **C**) an ultrasound scan image of the right kidney of this patient shows a haematoma. CT images reveal a large haematoma (**D** - a large CT section showing both the kidneys) including a mass of peri-nephric hyperdense collection (**E** - specific CT section to show the haematoma with a hyperdense collection around the right kidney) around the right kidney. Abbreviations shown in figures D and E: RK - right kidney; H - haematoma; HD - hyper dense area of haematoma/collection; LK - left kidney; IV - inferior vena cava; A - aorta; LI - large intestine; LS - lumbar spine; SP - spinous process; PM - psoas muscle. 'R' at the top of the CT images indicates the right orientation of the body. **F**) an angiogram showing the occlusion of arteries following selective coil angioembolisation.

7. Figure

Figure 1