COLOUR ATLAS OF FORENSIC TRAUMATOLOGY

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Version 1

Head Injuries

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FOREWORD

The greatest pleasure I experience as a teacher, is to see my students excel in their chosen careers and perform even better than myself. The series of e-booklets prepared to better equip medical officers to handle common conditions likely to be encountered in their day to day forensic practice by Professor Dinesh Fernando, is a good example of one of my students doing better than me!

Dinesh is the son of Emeritus Professor of Community Medicine, Former Head, Department of Community Medicine, Former Dean, Faculty of Medicine and Vice Chancellor of the University of Peradeniya, Malcolm Fernando, who was an illustrious medical academic. Following his father's footsteps, he joined the University of Peradeniya in 2003.

Dinesh was one of my post graduate trainees at the Department of Forensic Medicine and Toxicology, Faculty of Medicine, Colombo, and obtained the doctorate in Forensic Medicine in 2003. He underwent post-doctoral training at the Victorian Institute of Forensic Medicine, Melbourne, Australia, with my colleague and contemporary at Guy's Hospital Medical School, University of London, Professor Stephen Cordner. During this period, he served as the honorary forensic pathologist of the Disaster Victim Identification team in Phuket, Thailand following the tsunami, and was awarded an operations medal by the Australian Federal Police.

He has edited, and contributed chapters to, 'Lecture Notes in Forensic Medicine' authored by the former Chief Judicial Medical Officer, Colombo, Dr. L.B.L. de Alwis and contributed to 'Notes on Forensic Medicine and Medical Law' by Dr. Hemamal Jayawardena. He is the editor of the Sri Lanka Journal of Forensic Medicine, Science and Law. Continuing his writing capabilities, he has compiled an important and unique set of e-booklets which will be a great asset to undergraduate and post-graduate students of Forensic Medicine, and also to our colleagues. Its succinct descriptions of complicated medico-legal issues and clear and educational photographs are excellent. It makes it easy for the students to assimilate the theoretical knowledge of each topic as they have been augmented with histories, examination findings, macroscopic and microscopic photographs of actual cases. In some areas, photographs from multiple cases have been included, so that the students can better appreciate the subtle differences that would be encountered in their practice.

I sincerely thank my ever so grateful student Dinesh, for giving me this great honour and privilege to write the foreword.

Professor Ravindra Fernando

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Dr. Dinesh Fernando is a merit Professor in Forensic Medicine at the Faculty of Medicine, University of Peradeniya and honorary Judicial Medical Officer, Teaching Hospital Peradeniya. He obtained his MBBS in 1994 with Second class honours from the North Colombo Medical College, Sri Lanka, and was board certified as a specialist in Forensic Medicine in 2004. He obtained the postgraduate Diploma in Medical Jurisprudence in Pathology from London in 2005, and possesses a certificate of eligibility for specialist registration by the General Medical Council, UK. He underwent post-doctoral training at the Victorian Institute of Forensic Medicine, Melbourne, Australia. He has also worked at the Wellington hospital, New Zealand, as a locum Forensic Pathologist and as an Honorary Clinical Senior Lecturer at the Wellington School of Medicine and Health Sciences, University of Otago, New Zealand. He was invited to visit and share experiences by the Netherlands Forensic Institute in 2019.He was conferred a Fellowship by the College of Forensic Pathologists of Sri Lanka in 2021.

Dr. Diniki Agalawatte is a Temporary Lecturer at the Department of Forensic Medicine. She obtained her MBBS in 2025 with a second class honours from the Faculty of Medicine, University of Peradeniya.

PREFACE

Forensic Medicine in Sri Lanka encompasses, both, examination of patients for medico-legal purposes and conducting autopsies in all unnatural deaths, in addition to those that the cause of death is not known. In the eyes of the justice system in Sri Lanka, all MBBS qualified medical officers are deemed to be competent to conduct, report and give evidence on medico-legal examinations of patients and autopsies conducted by them, as an expert witness. However, during their undergraduate training, they may not get the opportunity to assist, nor observe, a sufficient variety of representative of cases that may be encountered in the future.

Therefore, a series of e-booklets has been prepared to better equip medical officers to handle common conditions that are likely to be encountered in day to day forensic practice. The case histories, macro and micro images are from cases conducted by Prof. Dinesh Fernando. Ms. Chaya Wickramarathne did a yeomen service in the initial designing of lay out and formatting the booklet. The compilation of the cases and photographs for publication was done by Dr. Diniki Agalawatte.

The content herein may be used for academic purposes with due credit given.

Any clarifications, suggestions, comments or corrections are welcome.

COLOUR ATLAS OF

FORENSIC TRAUMATOLOGY

ILLUSTRATIVE CASES

Head Injuries

Head Injuries

Head injury is one of the most frequently encountered conditions in forensic practice and remains a leading cause of morbidity and mortality globally. Whether resulting from road traffic accidents, assaults, falls, industrial mishaps, or firearm injuries, trauma to the head demands thorough forensic evaluation due to its medico-legal complexity and the potential for criminal investigation.

Head injuries can be broadly classified into scalp injuries, skull fractures, and brain injuries. Scalp injuries include abrasions, contusions and lacerations, Lacerations, although often minor, may bleed profusely and obscure more serious underlying trauma. Skull fractures can be linear, depressed, comminuted, diastatic, or basal, with each type carrying distinct forensic implications; for instance, a depressed fracture may indicate blunt force from a heavy or concentrated object. Brain injuries encompass several forms: concussion, which is a functional disturbance characterized by transient loss of consciousness without structural damage; contusion, involving bruising of brain tissue typically at coup (impact site) or contrecoup (opposite side) locations; laceration, resulting from tearing of brain tissue due to bony ridges or severe trauma; diffuse axonal injury (DAI), caused by shearing forces during acceleration-deceleration incidents such as high-speed collisions, often leading to prolonged unconsciousness or death. Traumatic brain hemorrhages include: epidural hematoma, commonly due to rupture of the middle meningeal artery and classically presenting with a lucid interval followed by rapid deterioration, usually in association with skull fractures; subdural hematoma, which results from rupture of bridging veins and is frequently seen in the elderly or chronic alcoholics; subarachnoid hemorrhage, which may occur following trauma or ruptured aneurysms; intracerebral hemorrhage, characterized by bleeding into the brain parenchyma.

In clinical practice, the latest classification of traumatic brain injury is the CBI-M framework which includes a clinical pillar,a biomarker pillar, an imaging pillar and a modifier pillar. In contrast, forensic medicine adopts a classification that reflects both the mechanism of trauma and the pathological features observed. Injuries may be considered open or closed, depending on whether the dura mater has been breached, and further divided into primary—those arising directly from mechanical forces at the time of trauma—or secondary, which develop later as complications such as cerebral edema, raised intracranial pressure, or herniation. They can also be described as focal, affecting a localized structure such as the scalp, skull, or a discrete brain region, or diffuse, where widespread neural or vascular damage is present, as seen in diffuse axonal injury or hypoxic–ischemic insults. From a mechanistic standpoint, head injuries include contusion resulting from direct impact and energy transfer, acceleration–deceleration injuries without direct impact leading to lesions such as subdural or subarachnoid hemorrhages, penetrating trauma from sharp objects, firearm-related wounds, as well as brain damage secondary to asphyxial events (e.g., hanging, strangulation) or toxic exposures such as carbon monoxide or other substances.

Comparison of meningeal haemorrhages

Features	Epidural	Subdural	Subarachnoid
Location	Between skull and dura	Between dura and arachnoid	Between arachnoid and pia
Cause	Usually associated with skull fracture and rupture of middle meningeal artery or its branches	Mostly rupture of bridging (communicating) veins draining into parasagittal sinuses	Natural: aneurysm, hypertension, angioma; Traumatic: cerebral contusions, arterial damage
Confusing entity	Can be confused with heat artifact	Seldom confused with other bleeding	Can be confused with an artefact caused when opening the skull during autopsy
External manifestation	Often blood under the scalp	Often no external manifestation	No external manifestation unless other injuries present
Effect	Usually space occupying	Often space occupying	May be space occupying if source is arterial
Distribution	Usually unilateral but can be bilateral	Unilateral or bilateral	Focal, semi-localised, bilateral, or diffuse
Brain surface	Compresses dura evenly causing “ruler straight” appearance of the underlying brain	Compresses gyri and sulci causing an “undulating” appearance of the underlying brain	Brain surface usually not distorted

History

A 15-year-old male was mountain biking with his friends. He was later found unconscious on the ground approximately 30 metres away from his bicycle. He was in a coma when he was admitted to the hospital. A craniectomy was performed, he remained in coma until treatment was withdrawn.

External examination

Four small abrasions (2 mm to 4 mm) on the back of the head in the midline were identified as evidence of external injury.

Internal examination

Central Nervous System: Reflection of the scalp revealed absence of the skull on the left parietal, left frontal, left temporal and part of the left occipital regions. The brain was herniating through the deficiency in the skull and had surface clotted blood of approximately 100 ml. A thin subdural haemorrhage measuring 9 cm x 10 cm with a thickness of 2 mm was present in the right temporoparietal region (20 ml). Part of the dura on the left side was absent. A laceration measuring approximately 2 cm in length was present on the lateral aspect of the left frontal lobe. Early necrosis of the left uncus was present. There was an intraventricular haemorrhage. An area of haemorrhage and necrosis was present in the cerebellum. Coronal sections of the cerebral hemispheres showed an area of necrosis and associated haemorrhage measuring approximately 3 cm x 3 cm in the left parieto-temporal region. Scattered haemorrhages were present throughout the white matter on both sides the largest of which was in the right parieto-occipital region. Cut section of the brainstem was free of haemorrhage.

All other system examinations were unremarkable.

Microscopic Examination

Central nervous system: Sections of brain showed areas of haemorrhage and necrosis with the presence of numerous retraction balls.

Figure 1: Stapled, craniectomy incision extending postero-laterally.

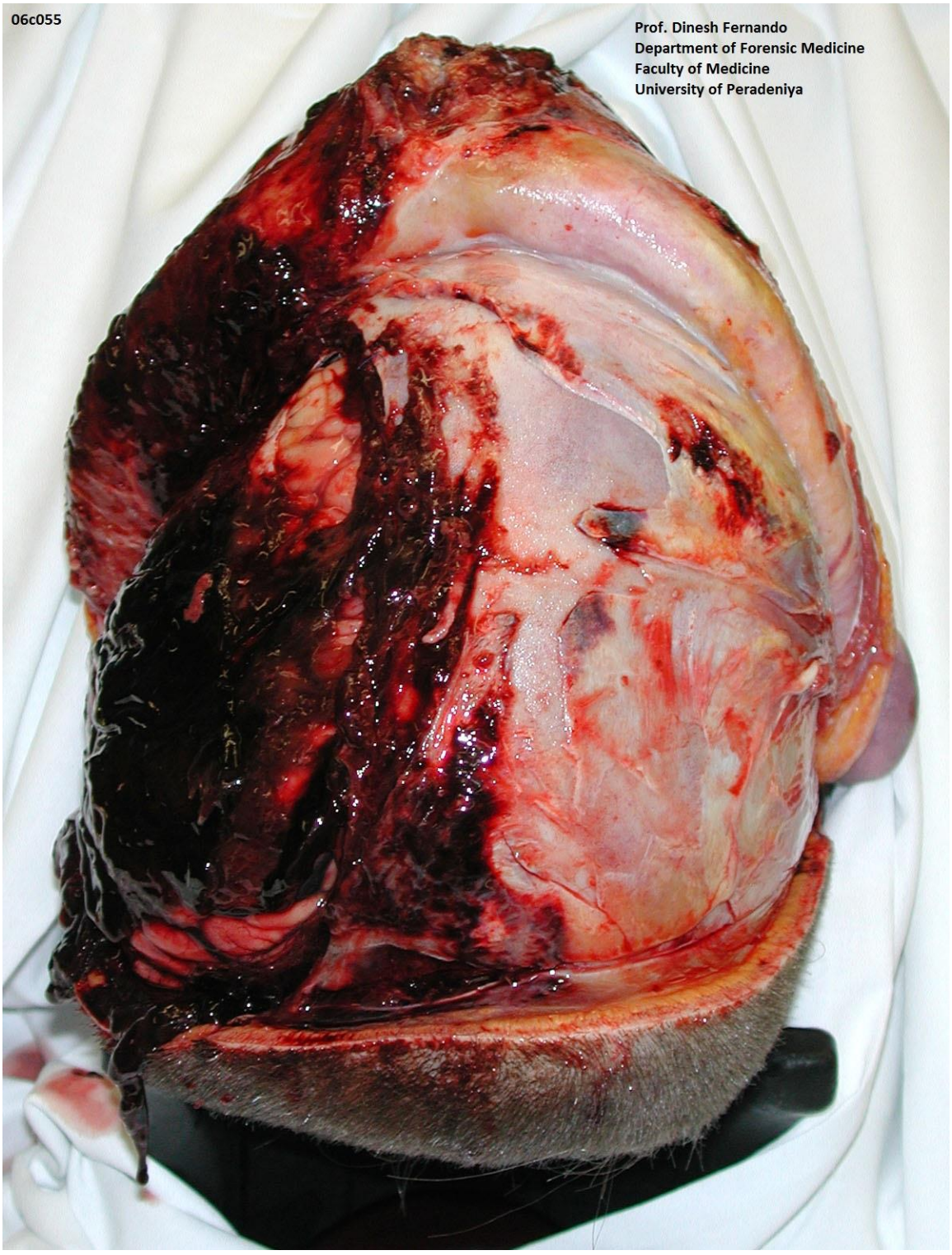

Figure 2: The brain with clotted blood on the surface herniating through the deficiency in the skull.

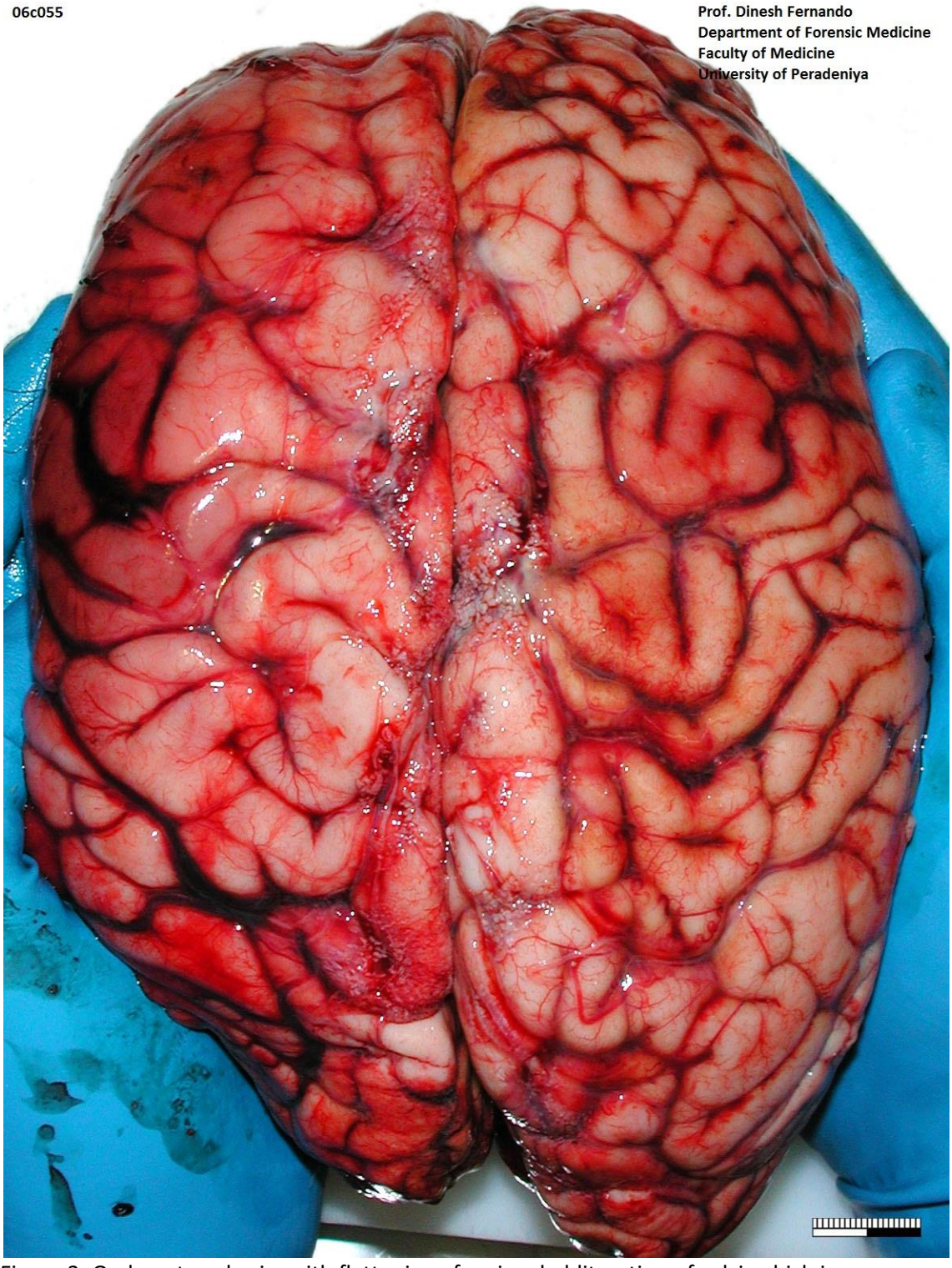

Figure 3: Oedematous brain with flattening of gyri and obliteration of sulci, which is more pronounced on the left side.

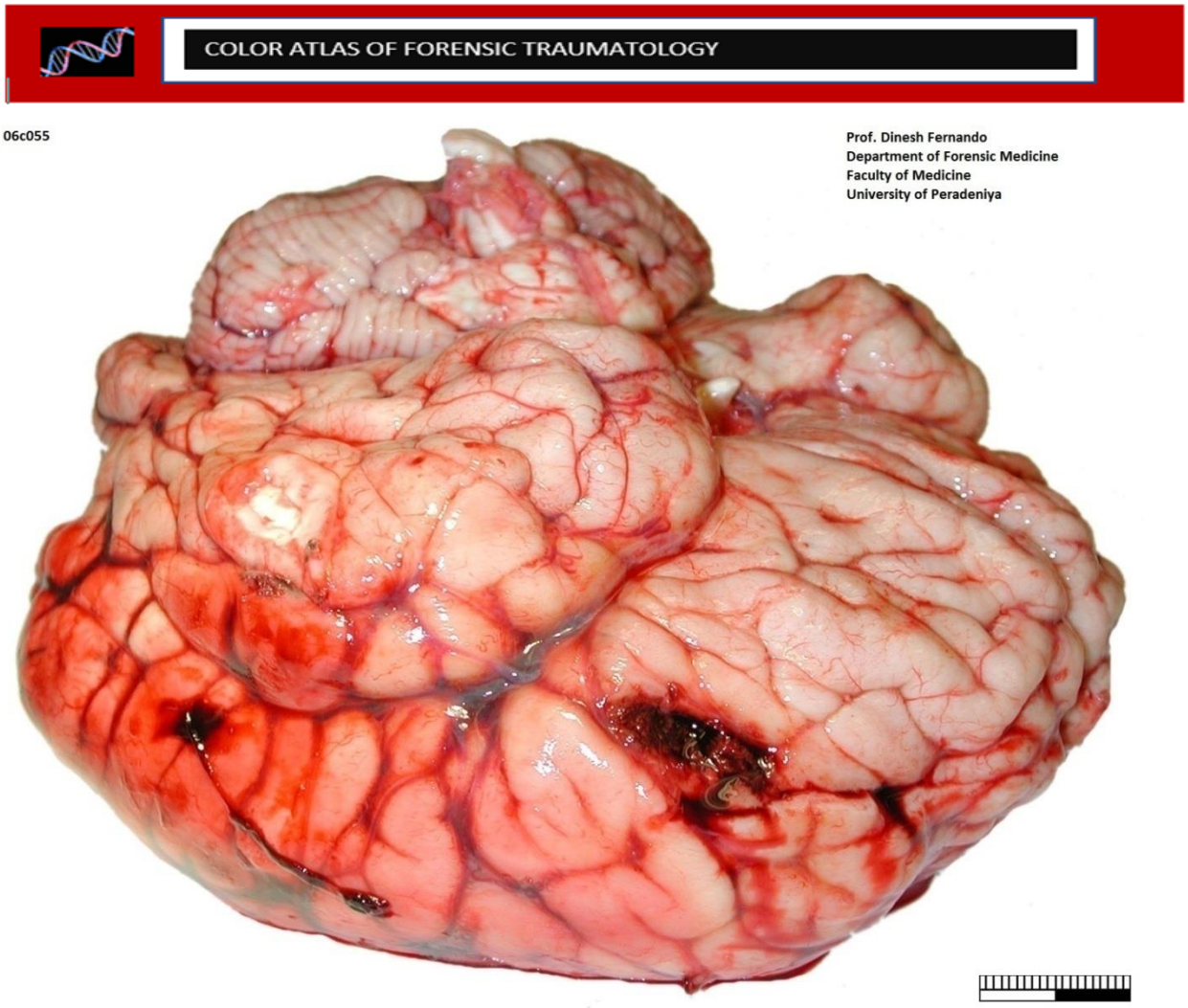

Figure 4: A laceration measuring 2 cm in length on the lateral aspect of the left frontal lobe.

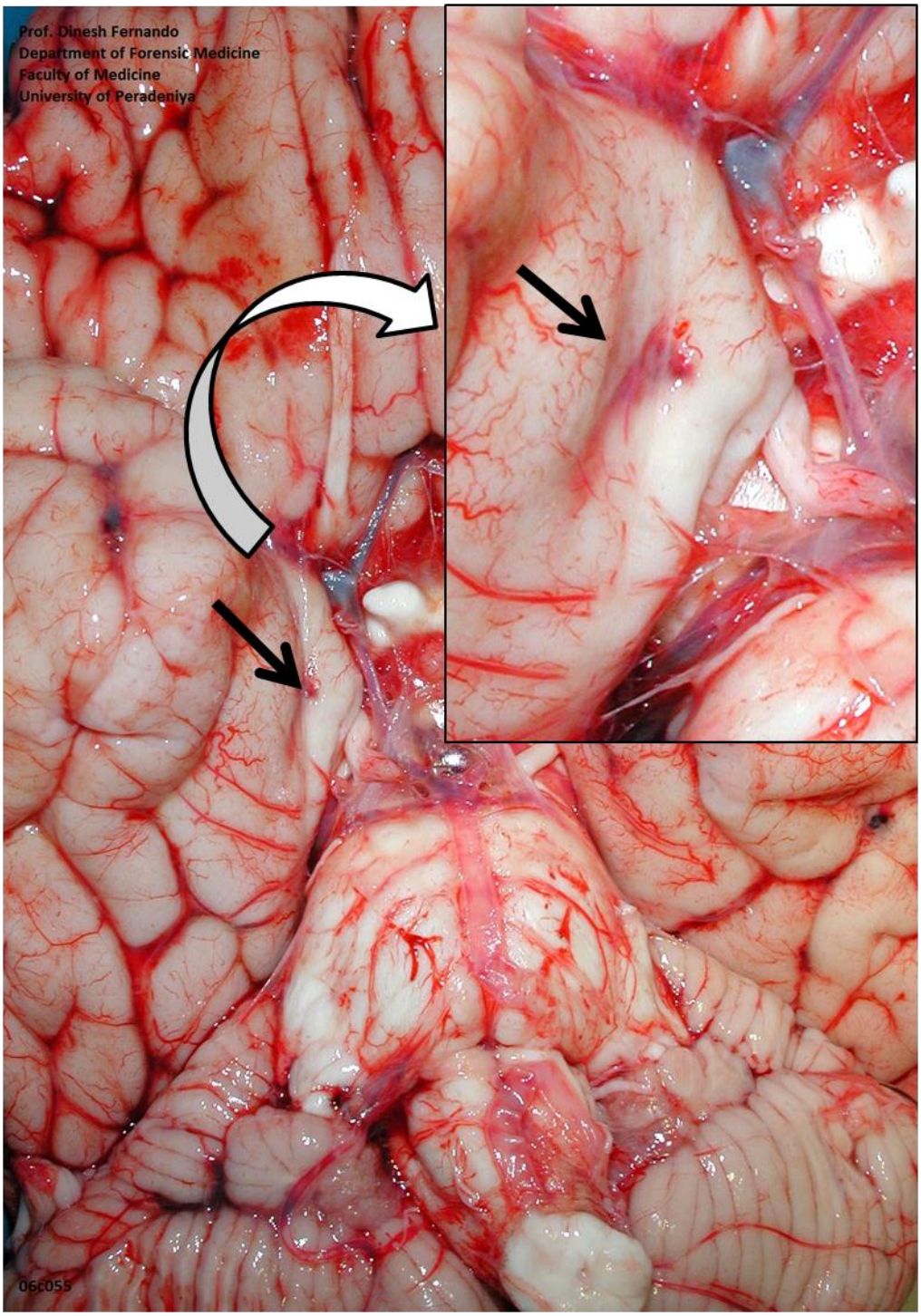

Figure 5: Grooving of the uncus due to impinging on the sharp margin of the tentorium.

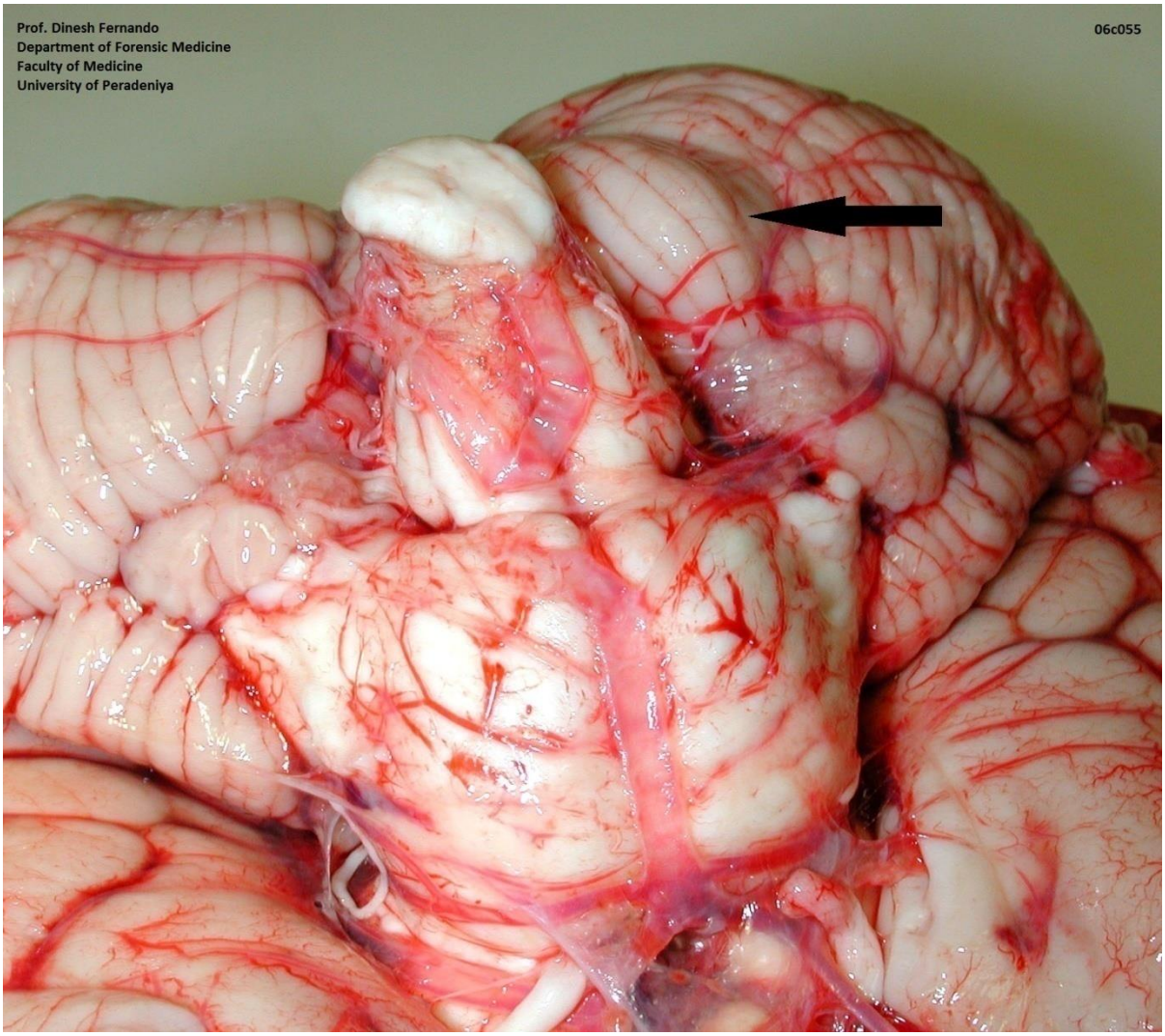

Figure 6: Grooving of the cerebellar tonsil due to herniation through the foramen magnum .

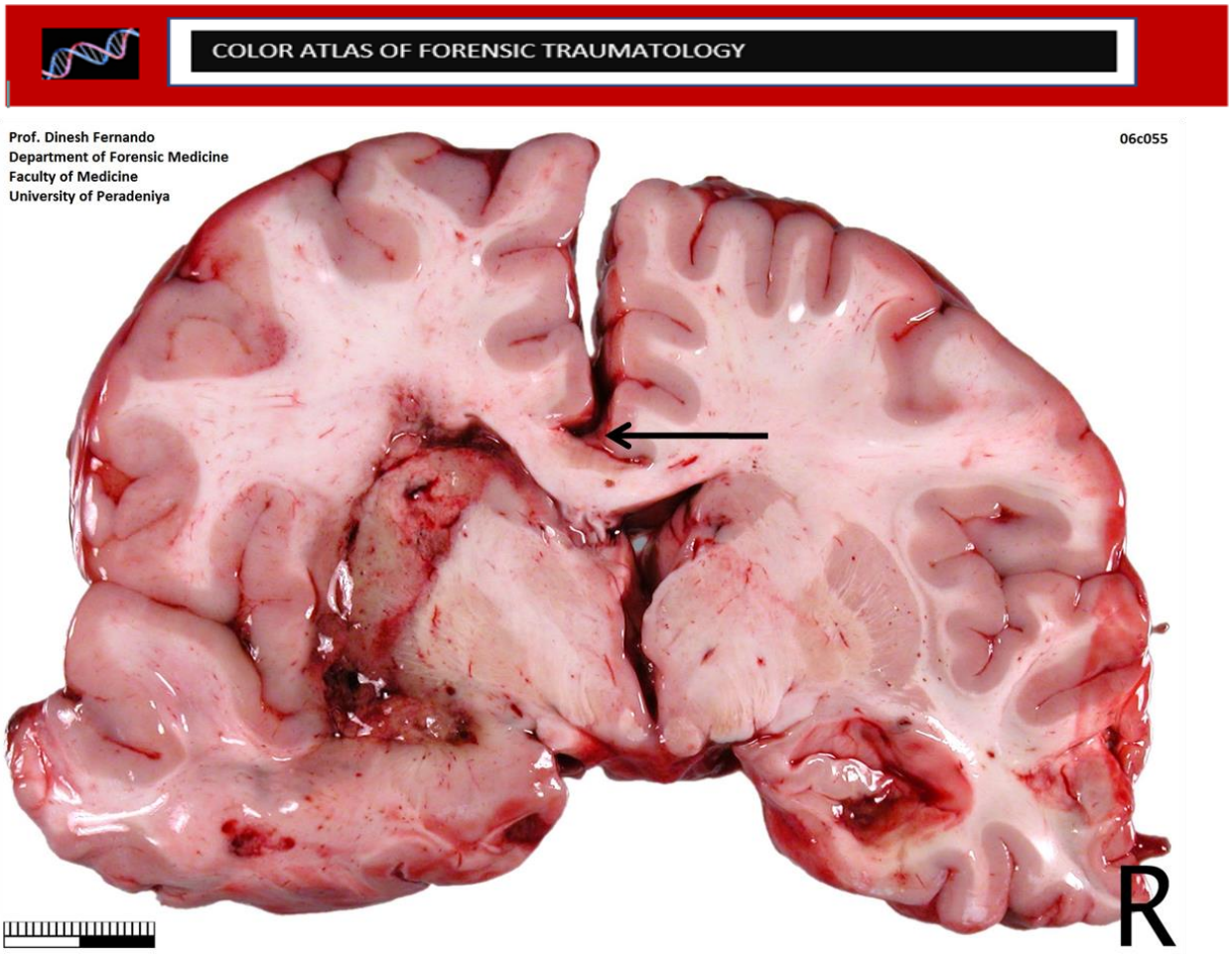

Figure 7: Herniation of the cingulate gyrus (subfalcine herniation). Note midline shift and necosis. For a schematic representation of brain herniation, please refer to page 7, chapter on Acute subdural haematoma, in volume I of the Colour Atlas of Forensic Pathology.

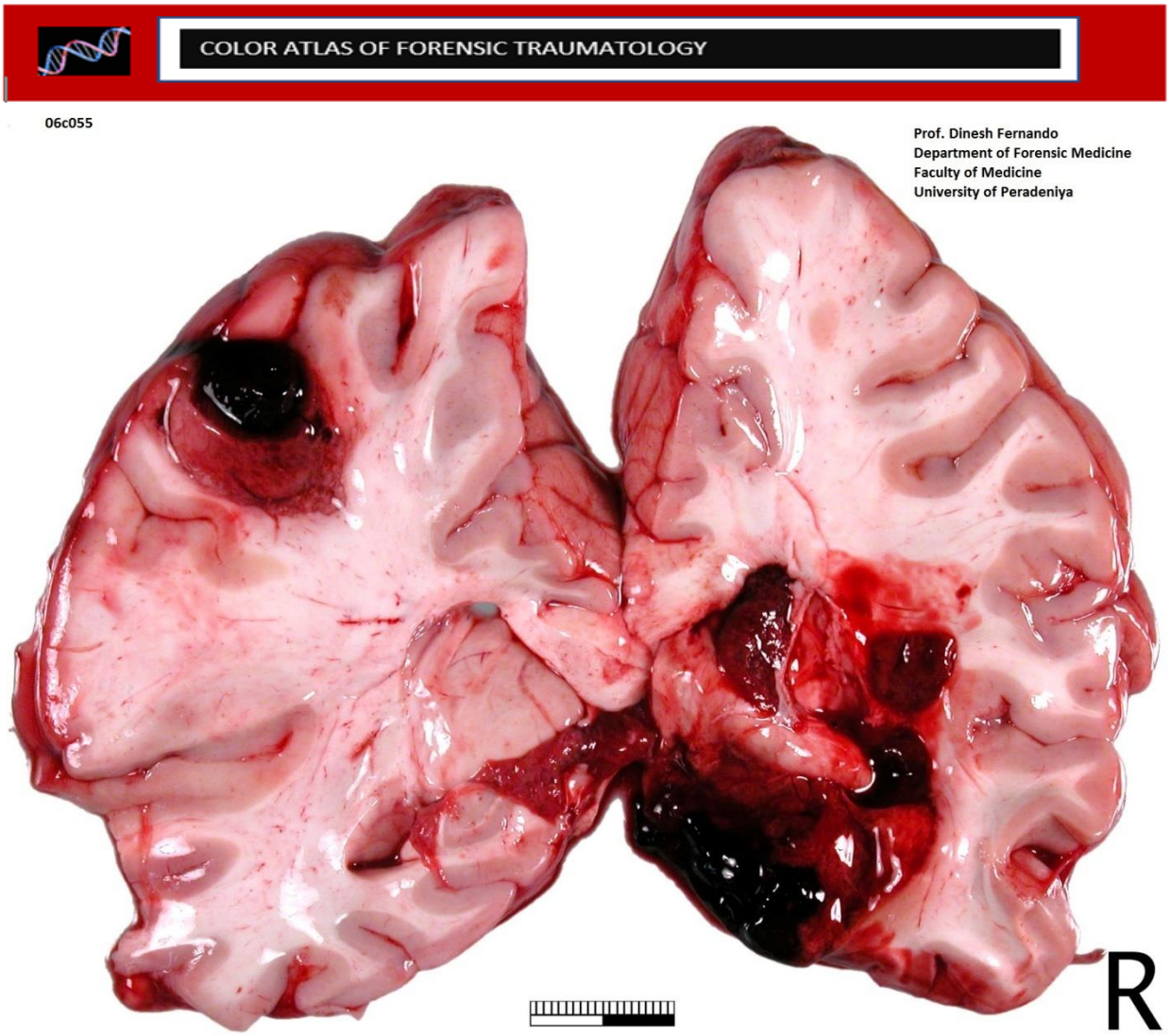

Figure 8: Intraventricular haemorrhage on the right and intra cerebral haemorrhage on left side.

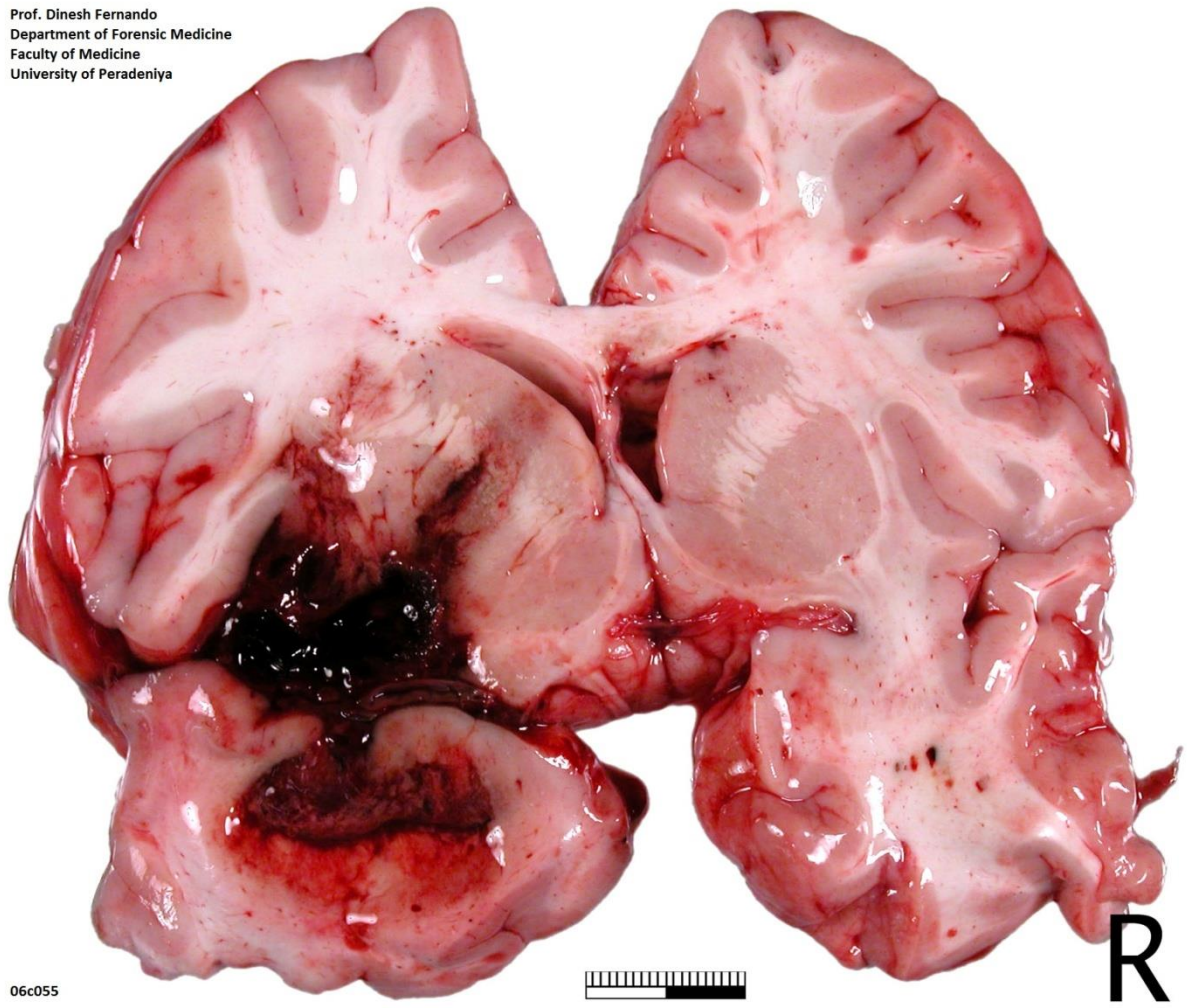

Figure 9: Cerebral hemisphere showing an area of necrosis and associated haemorrhage measuring 3 cm x 3 cm in the left parieto-temporal region. Note the scattered haemorrhages in the white matter.

Figure 10: An area of haemorrhage and necrosis present in the cerebellum.

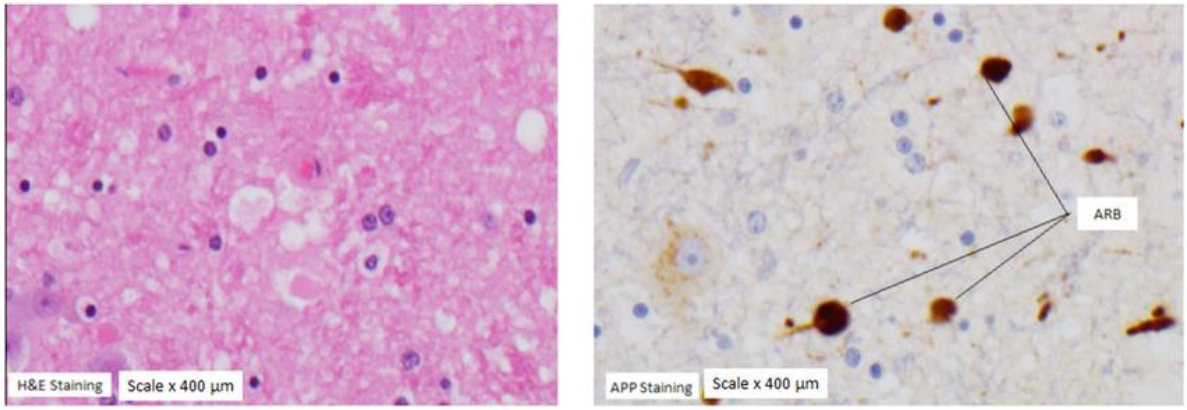

Figure 11: Axonal retraction balls (ARB). ARB under hematoxylin staining (left panel) and under amyloid precursor protein (APP) staining (panel on the right).

(Source: Bellapart J, Cuthbertson K, Dunster K, et al. Cerebral Microcirculation and Histological Mapping After Severe Head Injury: A Contusion and Acceleration Experimental Model. Front Neurol. 2018;9:277. Published 2018 May 7. doi:10.3389/fneur.2018.00277)

Cause of death

Head injury with diffuse axonal injury, intracerebral haemorrhage, intraventricular haemorrhage and cerebral laceration.

History

The deceased, who was on vacation, had fallen backwards while climbing the stairs to his hotel room, as witnessed by his wife. He had been unconscious for 4 to 5 minutes. He was confused once he recovered and the GCS was 13 at the emergency department. CT showed bifrontal contusions and a small left sided subdural haematoma. Since a clinical deterioration was observed, he underwent a decompression craniectomy. Repeat CT showed a large unilateral cerebellar infarct, widespread pneumatosis and air within the portal system. He had a past history of hypertension, paroxysmal atrial fibrillation and type 2 diabetes mellitus controlled on oral treatment.

Internal examination

Respiratory system: Multiple petechial haemorrhages were present on the pleura of both lungs and in the interlobar fissures. The pleural surfaces were smooth and glistening. The pulmonary parenchyma manifested congestion and extensive pulmonary oedema.

Gastrointestinal sysyem: The mucosa of the ileum and caecum appeared to be dark in colour and necrotic.

Central Nervous System: A 1 cm contusion on the inner aspect of the scalp was present on the back of the head 1 cm to the right of the midline. Extensive contusions were present on the scalp in relation to the surgical incision and also involved the bilateral temporalis muscles. The frontal bone had been removed at surgery leaving a large anterior deficiency of the skull through which the brain was bulging out. The 1,534 gram brain showed extensive herniation through the craniectomy and had flattening of gyri and obliteration of sulci. A thin subarachnoid haemorrhage and subdural haemorrhage was present on the inferior aspects of both frontal lobes.

Extensive bilateral contusion and laceration of the frontal lobes were present with associated necrosis of brain tissue. A contusion was present on the inferior aspect of the left temporal lobe. Multiple cross sections of the cerebral hemispheres showed contusion, laceration and necrosis of both frontal lobes extending to the parietal lobes, involving the anterior horns of the ventricles. Punctate haemorrhage and necrosis was seen on the corpus callosum. The cerebellar tonsils appeared to be elongated but were not necrotic macroscopically. Cross sections of the cerebellum showed necrosis of the right cerebellum.

The ventricles were dilated and communicated with the laceration and contusion of the frontal lobes. Stripping the dura from the skull revealed a 11 cm linear fracture commencing 1 cm to the right of the midline in the occipital bone extending up to the right margin of the foramen magnum.

Microscopic examination

Respiratory system: Sections of the lungs showed areas of collapse with lobar pneumonia.

Gastrointestinal system: Sections of the small bowel and the caecum showed transmural acute infarction. Fibrin thrombi seen in submucosal vessels.

Central nervous system: Sections of the brain confirmed the presence of a subarachnoid haemorrhage. There was an organising infarction of the cingulate gyrus and corpus callosum which may represent either a separate focus of trauma or be continuous with the injury to the frontal lobe. An organising contusion with some ischaemia was seen in the frontal lobe. Sections of the cerebellum showed an infarct with pink neurons, haemorrhage and foamy macrophages indicating a duration of three to five days.

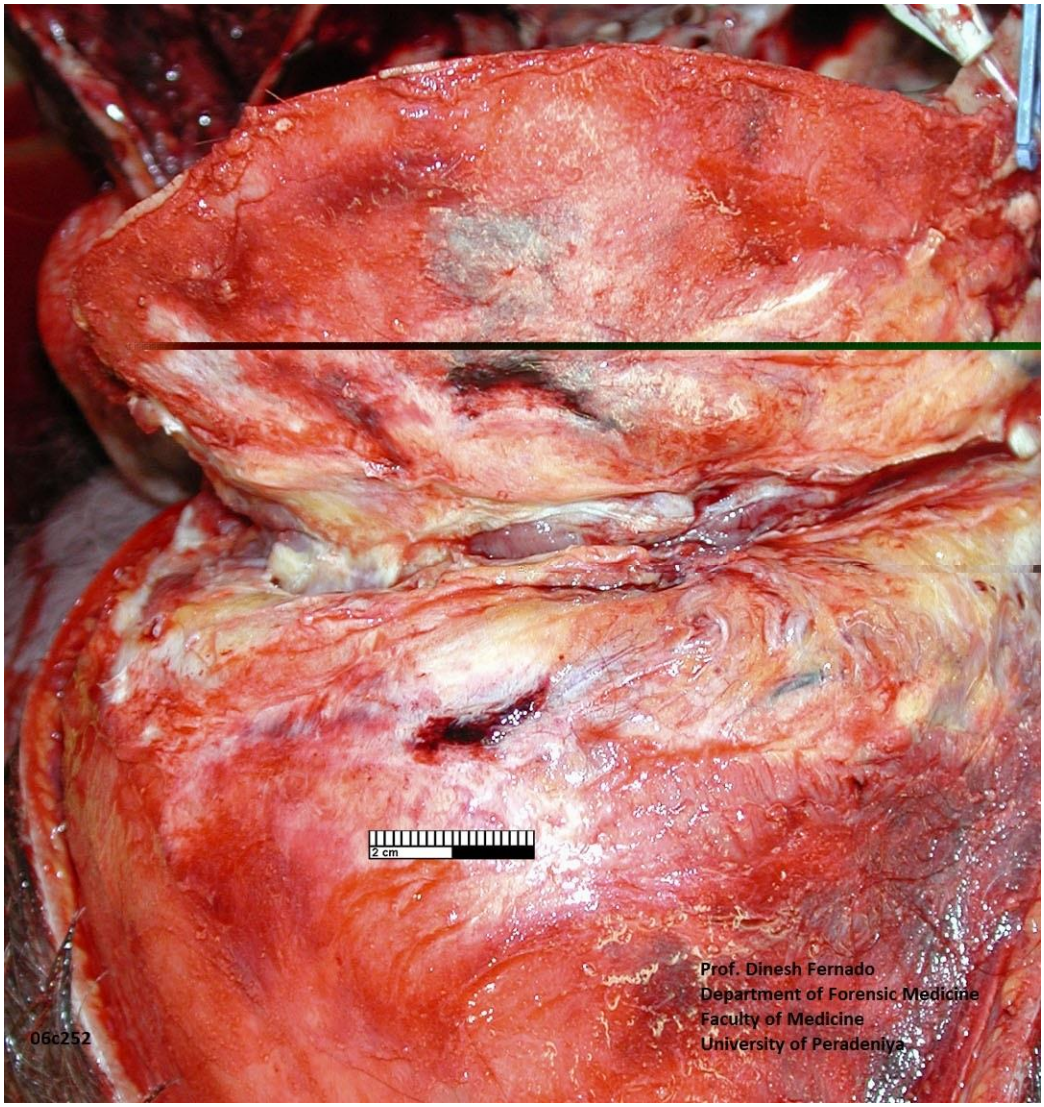

Figure 1: A discrete, 1 cm contusion on the inner aspect of the scalp on the back of the head.

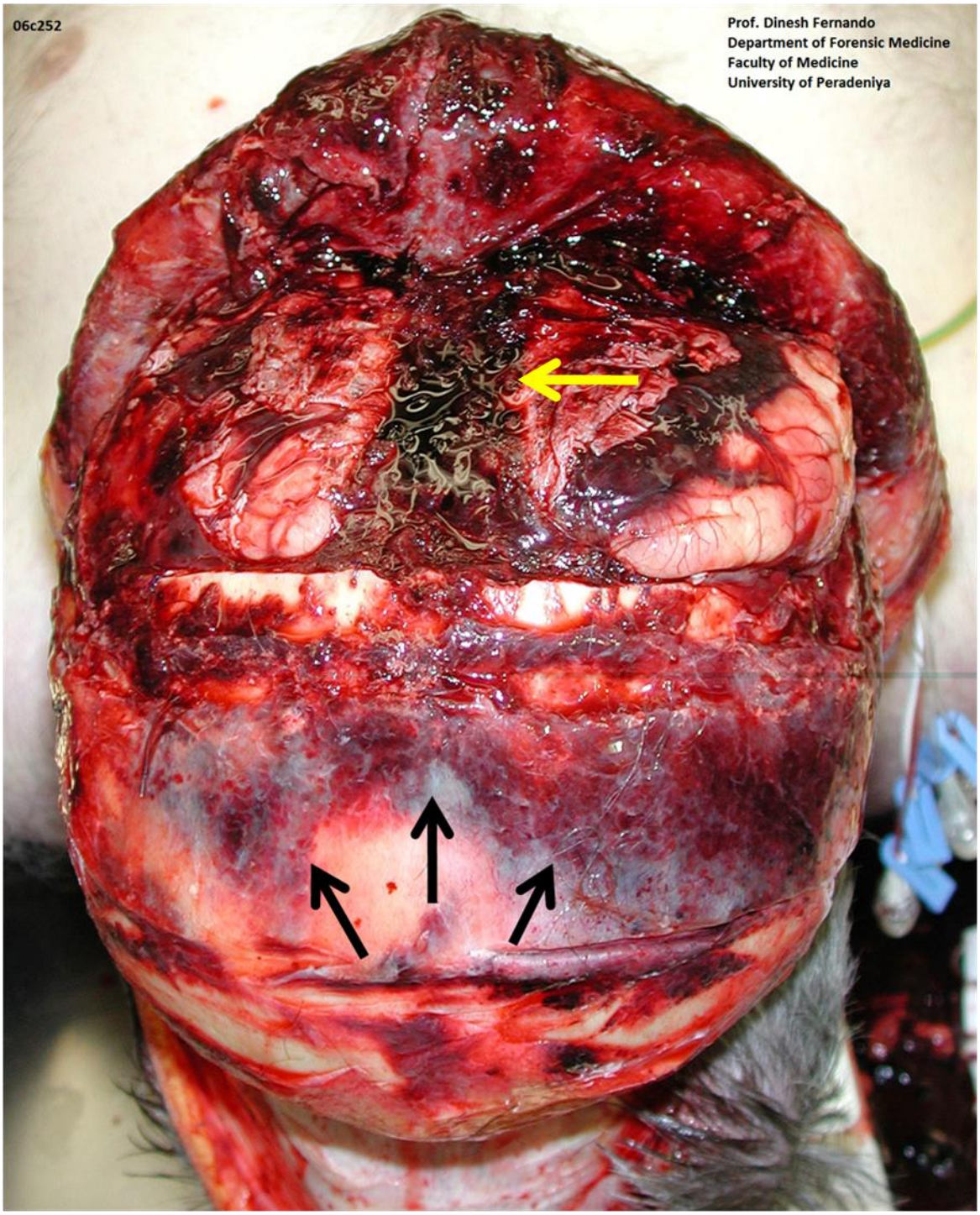

Figure 2: Extensive contusions on the inner aspect of the reflected scalp (black arrows) with clotted blood on the surface of the brain (yellow arrow) visible through the craniectomy.

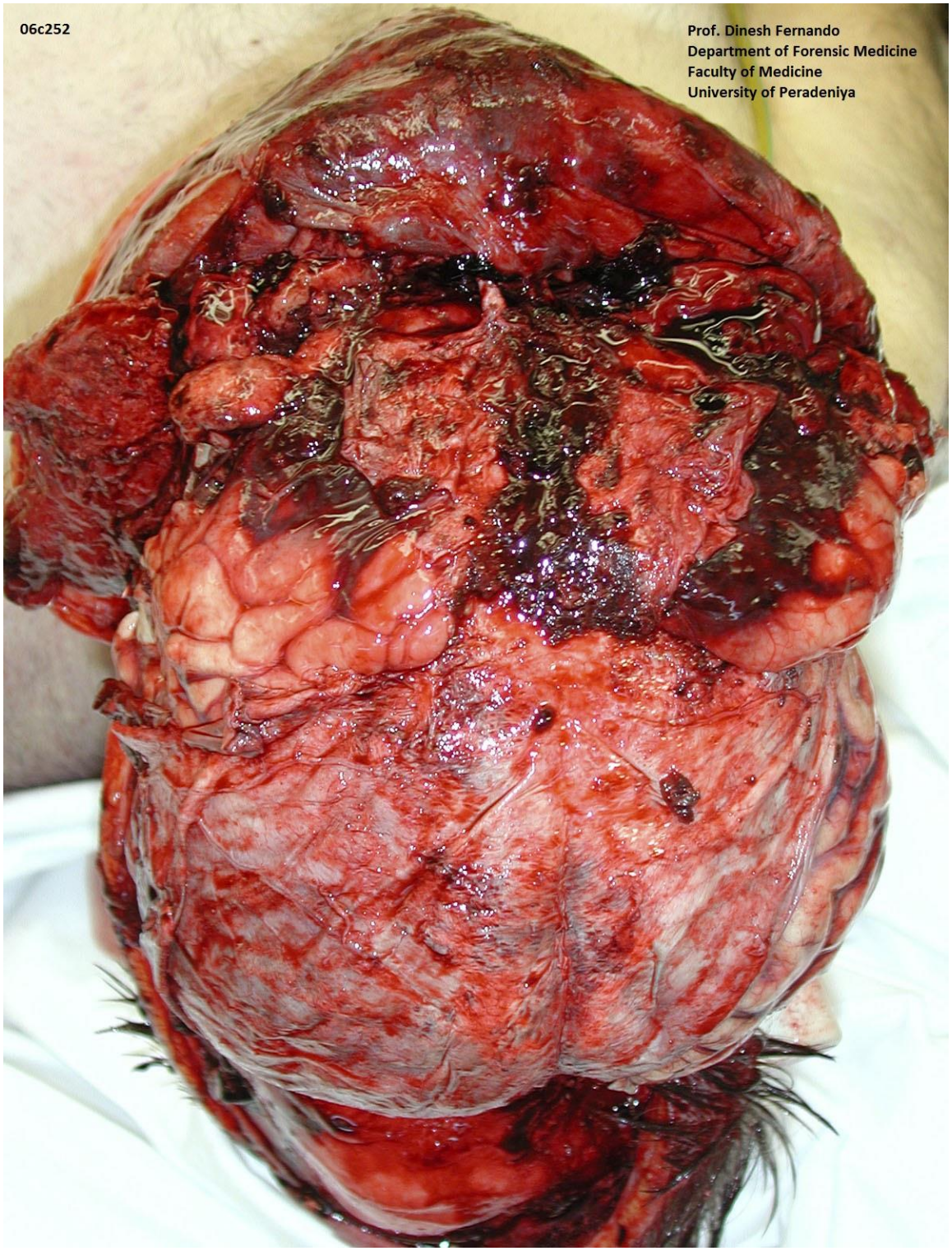

Figure 3: Posterior part of skull removed showing the brain covered by dura. The oedematous brain is herniating through the craniectomy. Bilateral contusion and laceration of the frontal lobes is seen.

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Figure 4: Extensive contusion and laceration of both frontal lobes and contusion of left temporal pole. Note the thin subarachnoid haemorrhage and minimal subdural haemorrhage.

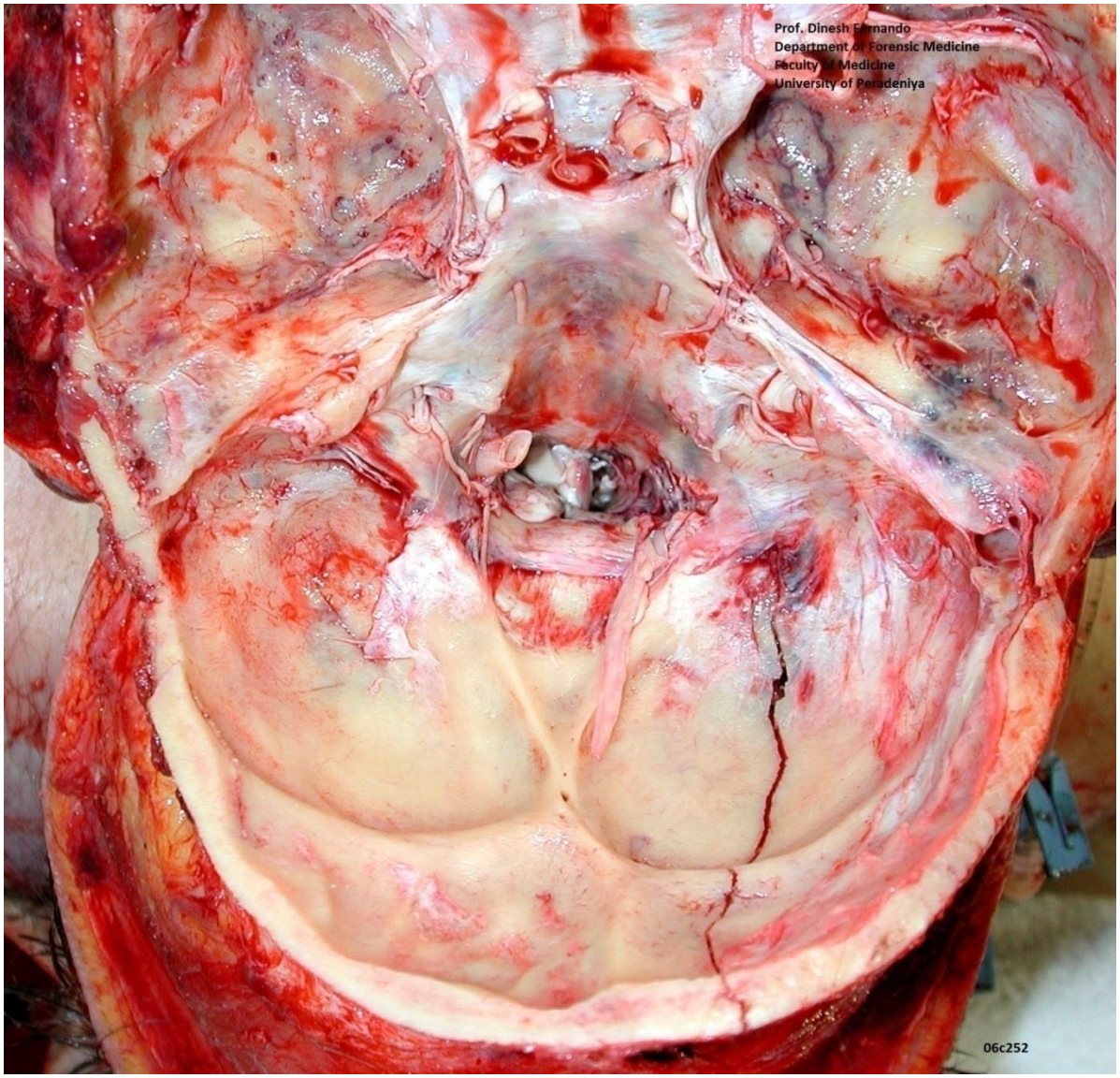

Figure 5: A linear fracture on the right posterior cranial fossa.

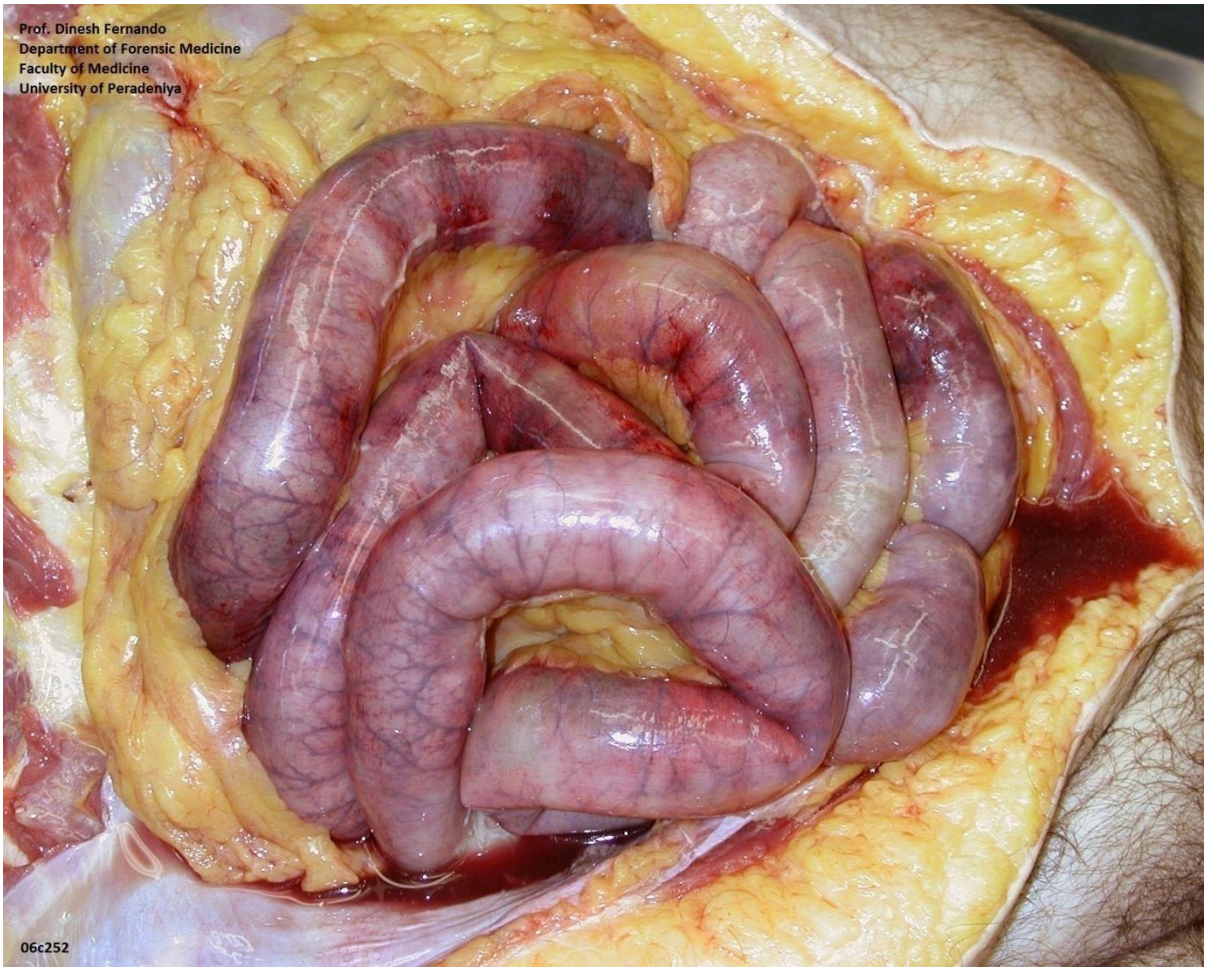

Figure 6: Distended, dark and necrotic ileum.

Cause of death

Head injury with impact on the back of the head on a hard surface, compatible with the history of fall backwards.

Pneumonia and infarction of the bowel which are complications of head injury were contributory causes.

History

The deceased was the driver of a car that was hit by a truck on the driver's door at an intersection. The truck was travelling at approximately 80 kms per hour. The truck has then pushed the car across the lane and into the opposite lane; a distance of 40 metres. She was pronounced dead at the scene.

External examination

There was a laceration just to the right of the midline on the top of the head with an underlying scalp contusion. Contusions found on the lateral aspect of the upper right chest, lateral aspect of the right arm. A group of five abrasions seen on the top of the top of the right shoulder. An imprint type contusion was seen on the lateral aspect of the right hip and upper thigh. Two lacerations were seen on the palm of the left hand. Obliquely placed contusion on the lateral aspect of the lower right thigh with a circular imprint at the upper anterior end was seen. Two abrasions were found on either side along the margin of contusion. Impression-imprint of window winding handle and knob. (Fig 1)

Internal examination

Cardiovascular system: Up to a maximum of 50% occlusion by eccentric atheroma was present in the left anterior descending coronary artery. A tear on the right internal mammary artery was present underlying fracture of the first rib close to the manubrium.

Respiratory system: The right pleural cavity contained 150 ml of fresh blood and the left pleural cavity contained approximately 20 ml of fresh blood. The pulmonary parenchyma manifested mild contusions.

Liver and billiary tract: Several small (approximately 1.5 cm) lacerations were present within the substance of the right lobe of the liver.

Musculoskeletal System: Complete disruption of the atlanto-occipital joint. On the right, the second to twelfth ribs were fractured posteriorly, second to sixth ribs were fractured laterally and the first and second ribs were fractured anteriorly causing a tear of the internal mammary artery. On the left, the second to fifth ribs were fractured anteriorly. The right clavicle was fractured medially.

Central Nervous System: The 1,238 gram brain had a congested external appearance. Thin diffuse subarachnoid haemorrhage was present over the convexities and around the base of the brain. Multiple cross sections of the cerebral hemispheres revealed punctate haemorrhages scattered throughout the white matter on the right inner parasagittal location (frontal, basal ganglia and thalamus). Transection of the brainstem at the ponto-medullary junction and a partial tear between the cerebral peduncle of the midbrain and pons was present. Haemorrhage was present along the anterior aspect of the cervical spine. Complete disruption of the atlanto-occipital joint was present.

Figure 1: Contusion measuring approximately 11 cm x 4 cm obliquely placed on the lateral aspect of the lower right thigh with a circular imprint measuring 2.5 cm in diameter at the upper anterior end. Impression: imprint of window winding handle and knob seen in older cars.

Figure 2: Contusion involving the lateral aspect of the right arm with multiple abrasions ranging from 0.5 cm to 3 cm in diameter on the outer aspect of the right arm.

Figure 3: A contusion measuring 5 cm in diameter just to the right of the midline on the inner aspect of the scalp. A 2 cm laceration was present on the overlying scalp.

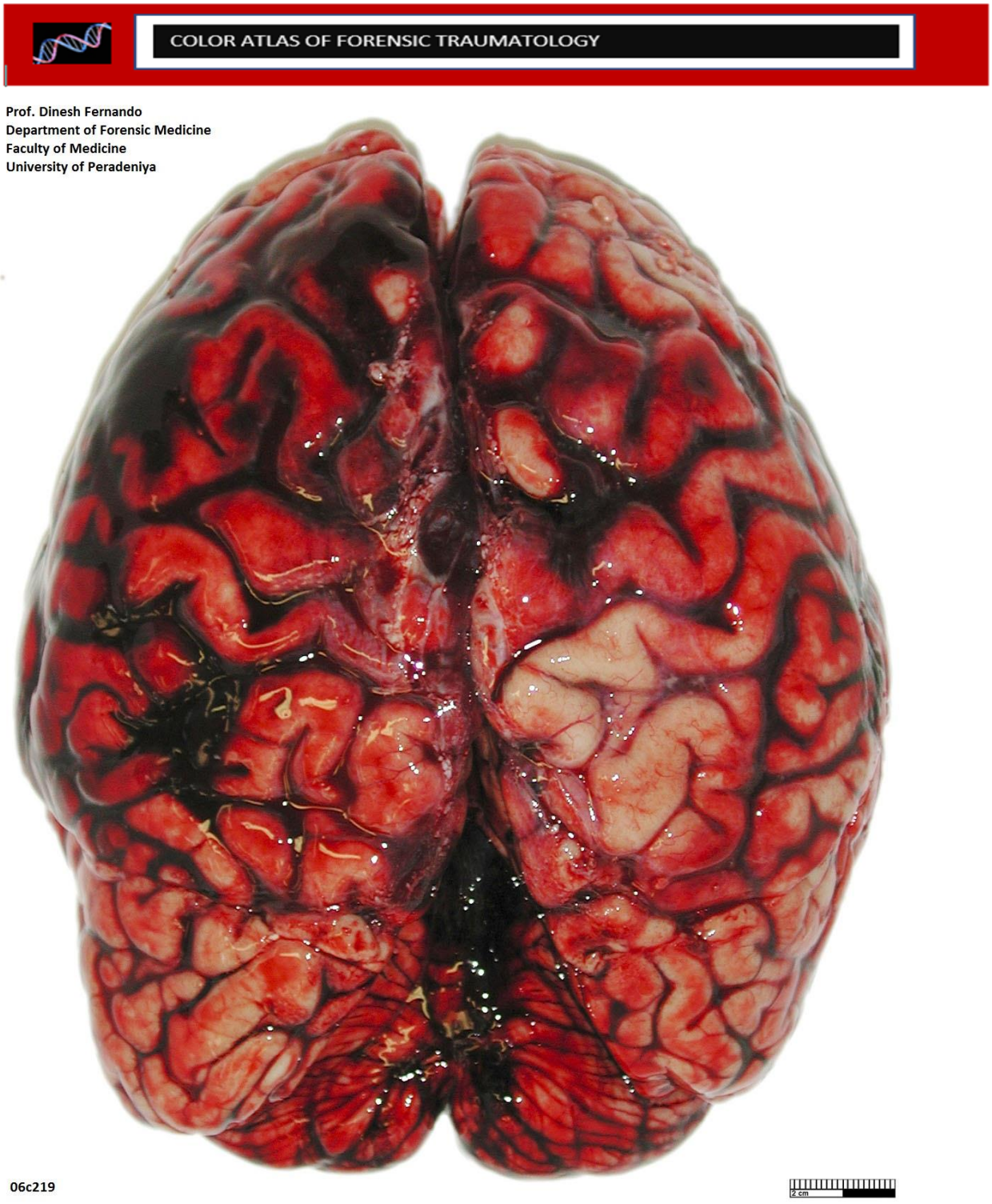

Figure 4: Diffuse subarachnoid haemorrhage over the convexities of the brain.

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Figure 5: A small subarachnoid haemorrhage around the brainstem.

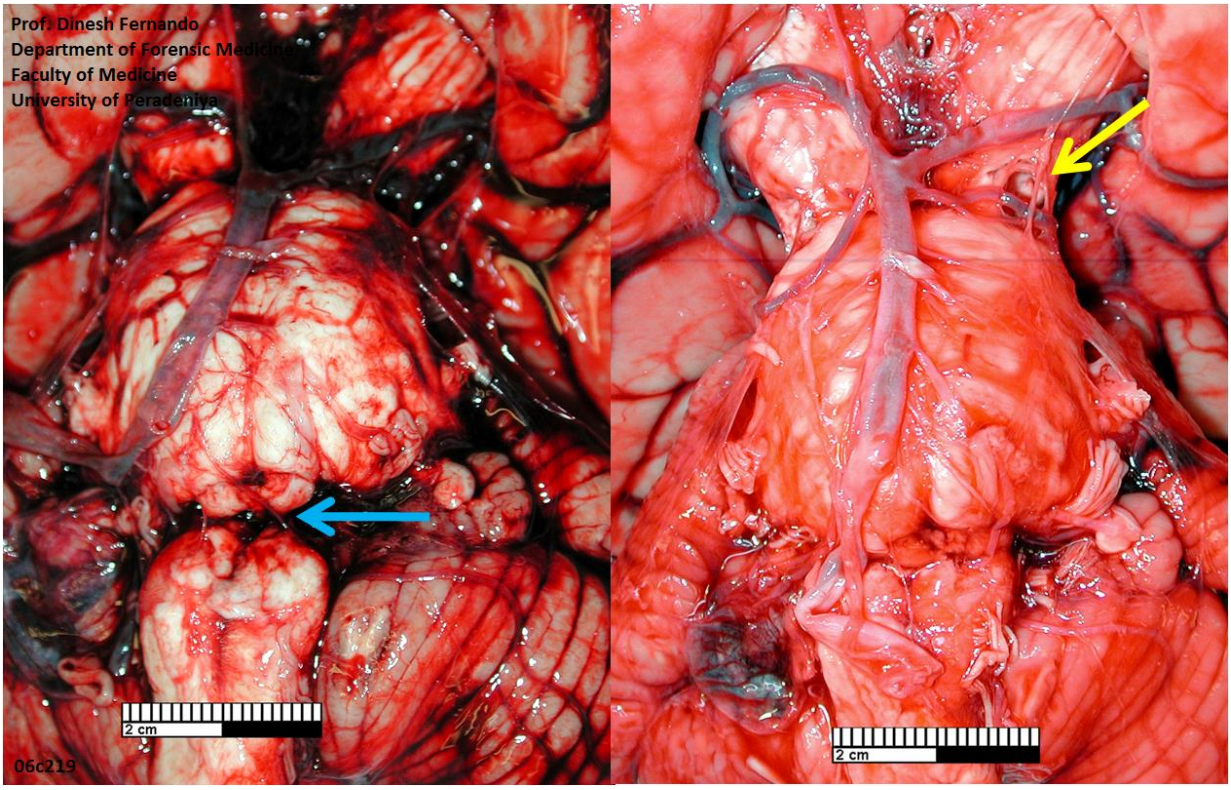

Figure 6: Transection of the brainstem at the ponto-medullary junction (blue arrow) and a partial tear between the cerebral peduncle and pons (yellow arrow).

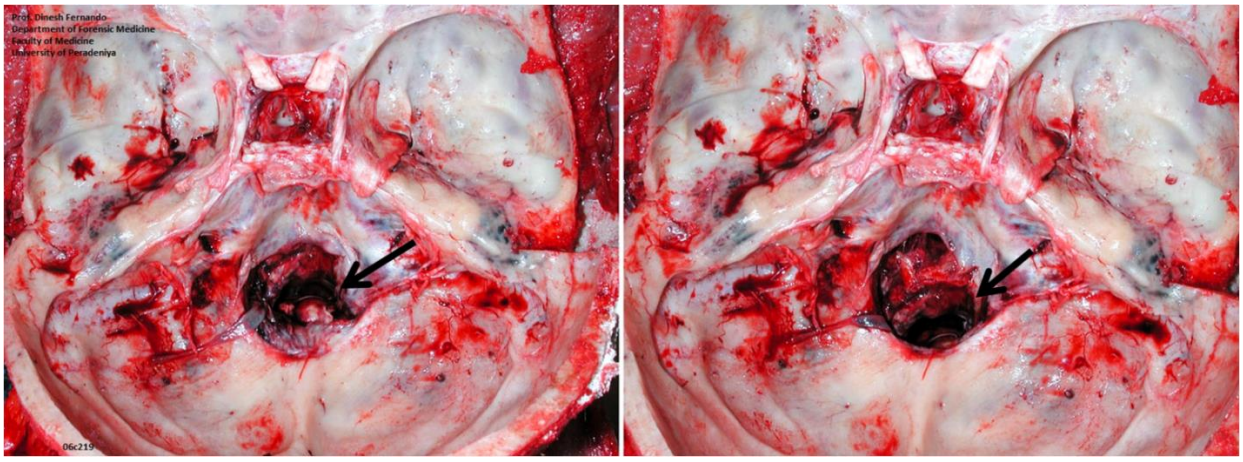

Figure 7: Complete disruption of the atlanto-occipital joint causing increased mobility and reduced cervical spinal canal space (arrows indicate the narrowing of the canal space).

Cause of death

Head Injury. The injuries sustained are consistent with the history of a side impact motor vehicle collision.

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