DELAYED RECOGNITION OF ACUTE AORTIC DISSECTION

Healthcare Safety Investigation I2017/002b

January 2020 Edition

PROVIDING FEEDBACK AND COMMENT ON HSIB REPORTS

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ABOUT HSIB

The Healthcare Safety Investigation Branch (HSIB) conducts independent investigations of patient safety concerns in NHS-funded care across England.

Most harm in healthcare results from problems within the systems and processes that determine how care is delivered. Our investigations identify the contributory factors that have led to harm or have the potential to cause harm to patients. The recommendations we make aim to improve healthcare systems and processes in order to reduce risk and improve safety.

Our organisation values independence, transparency, objectivity, expertise and learning for improvement.

We work closely with patients, families and healthcare staff affected by patient safety incidents, and we never attribute blame or liability to individuals.

A NOTE OF ACKNOWLEDGEMENT

HSIB would like to thank Richard's partner, who was present throughout Richard's care, for her time in sharing her recollection of the events and experiences which are central to this report. Her continued engagement and support has enabled a much richer perspective of the incident through the eyes of the family.

HSIB would also like to express its gratitude to the healthcare professionals who looked after Richard and who gave their time to assist with the investigation, providing open and honest accounts of events to support learning and improve patient safety.

OUR INVESTIGATIONS

Our team of investigators and analysts has diverse experience working in healthcare and other safety-critical industries and have expertise in human factors analysis, safety science and the design of safety management systems. We consult widely in England and internationally to ensure that our work is informed by appropriate clinical and other relevant expertise.

We currently undertake two types of patient safety investigation.

NATIONAL INVESTIGATIONS

Our national investigations can encompass any patient safety concern that occurred within NHS-funded care in England after 1 April 2017. The topics we select are informed by suggestions provided by healthcare professionals and the public, and our own analysis of NHS patient safety databases and reporting.

We decide what to investigate based on the scale of risk and harm, the impact on individuals involved and on public confidence in the healthcare system, as well as the potential for learning to prevent future harm. We welcome information about patient safety concerns from the public, but we do not replace local investigations and cannot investigate on behalf of families, staff, organisations or regulators.

Our investigation reports identify opportunities for relevant organisations with power to make appropriate improvements through:

- *'Safety recommendations'* made with the specific intention of preventing similar events happening in the future

- *'Safety observations'* with suggested actions for wider learning and improvement.

Our reports also identify 'safety actions', which are steps identified during an investigation as being immediately necessary to improve patient safety.

We ask organisations subject to our safety recommendations to respond to us within 90 days. These responses are published on the investigation pages of our **website**.

MATERNITY INVESTIGATIONS

Since 1 April 2018, we have been responsible for all patient safety investigations of maternity incidents occurring in the NHS in England which meet criteria for the **Each Baby Counts programme**.

The purpose of the HSIB maternity investigations programme is to achieve rapid learning and improvement in maternity services, and to identify common themes that offer opportunity for system-wide change. For these incidents HSIB's investigation replaces the local investigation, although the NHS trust remains responsible for meeting the Duty of Candour and for referring the incident to us.

We work closely with parents and families, healthcare staff and organisations during an investigation. Our reports are provided directly to the families involved and to the trust. The trust is responsible for actioning any safety recommendations we make as a result of these investigations.

Our longer-term aim is to make safety recommendations to national organisations for system-level improvements in maternity services. These recommendations will be based on common themes arising from our trust-level investigations.

EXECUTIVE SUMMARY

Introduction

The aorta is the main blood vessel leaving the heart, carrying oxygenated blood to be distributed to all parts of the body. Aortic dissection is a rare but life-threatening condition in which a split develops in the wall of the aorta, allowing blood to flow between its layers, which can result in catastrophic rupture of the aorta and death if not treated urgently. Depending on the type of dissection, surgical repair may be required.

This investigation was initiated as a result of the death of a 54-year-old man following an aortic dissection, in which there was a delay of around four hours in recognising the diagnosis. The investigation found that existing data do not allow a good understanding of the number of people who have an aortic dissection and their outcomes, but there may be around 2,500 cases a year in England. The length of delay before diagnosis in this case is not unusual; aortic dissection is uncommon and often difficult to diagnose, but there are existing and potential ways in which this can be improved.

The reference event

Richard was a fit 54-year-old man who experienced severe sudden onset chest pain while lifting weights in the gym. Although the pain subsequently reduced, he still felt unwell. After returning home and calling the NHS 111 service, Richard was taken to the emergency department (ED) of a local acute hospital by ambulance. The ambulance paramedics believed that the cause of the pain was probably musculoskeletal (from the muscles, bones or joints) but felt there was a need to rule out an acute myocardial infarction (heart attack).

After waiting over 30 minutes for triage and, on his case being assigned as priority two (out of five, with one being the most urgent), Richard was placed in a low-dependency cubicle. During his time in the ED, Richard was seen by an advanced care practitioner and a second-year trainee doctor. The trainee doctor discussed the case with, and received advice from, a consultant. Richard initially appeared well but his condition subsequently deteriorated with further pain, nausea, vomiting and diarrhoea. His electrocardiogram (ECG) was normal but blood tests showed a very raised level of a significant blood chemical (D-dimers more than 3000ng/ml).

After three hours in the department with no clear diagnosis, Richard was referred to the on-call medical team. The medical registrar was concerned about the possibility of an acute aortic dissection (AD) and requested an urgent computed tomography aortogram (CTA) scan, which confirmed the diagnosis of an extensive aortic dissection (Stanford type A). After an hour waiting for a formal report of the scan, Richard was sent by ambulance to the regional specialist centre for heart and chest surgery but suffered a cardiac arrest during the journey and died.

The national investigation

The Healthcare Safety Investigation Branch (HSIB) was contacted by an ambulance trust regarding Richard's case. Following initial information gathering and evaluation of the safety issues, the HSIB Chief Investigator authorised a safety investigation.

The investigation gathered evidence to build as complete a picture as possible of the events leading to Richard's death. As the investigation progressed, the complexity of the case became apparent. In particular, there were important safety issues related to the diagnostic processes in the ED, the preparation of the patient for transfer between hospitals and the transfer itself.

A decision was taken to divide the investigation into two parts; part one, which focussed on the transfer of critically ill adults, was published in January 2019 (Healthcare Safety Investigation Branch, Transfer of critically ill adults 2019b).

This report details the analysis and findings of the second part of the investigation, which sought to understand the factors affecting the recognition of acute AD in the ED.

In addition to evidence gathered in the course of the investigation into Richard's case (the reference event), the wider investigation has used published data, available literature and other research to understand the scale and impact of acute AD, why the diagnosis of this condition might be delayed and what remedies might be available to make early diagnosis more likely.

The investigation has found that, although treatment outcomes have improved, acute AD remains an infrequent but very hazardous event, the incidence of which is likely to increase as the population ages. Some measures which could be implemented relatively rapidly to reduce the safety risk have been identified, together with the need for longer term data collection and development of strategies to reduce delays in diagnosis.

Findings from the reference event

- The medical professionals who treated Richard prior to his hospital admission and in the ED did not recognise that the sudden onset of severe chest pain might be a symptom typical of acute AD.

- There appeared to be a lack of awareness among medical staff of the most common symptoms and signs of acute AD and the limitations of measuring the blood pressure in both arms as a diagnostic test for this condition. There also appeared to be confusion for some staff between the presentation of an acute thoracic AD and an abdominal aortic aneurysm.

- The NHS 111 triage resulted in an appropriate response, but the patient was advised to take aspirin, which could have had serious adverse consequences in this condition.

- Richard was taken to hospital to rule out an acute myocardial infarction as the cause of chest pain. However, he waited over 30 minutes for triage and, although his case was assigned to priority two (of five, with one being the most urgent), Richard was then placed in a low-dependency cubicle.

- Although Richard's pain could not be reproduced in a way which would have positively supported the presence of a musculoskeletal injury, there was some reluctance to relinquish this as a possible diagnosis while the possibility of a more serious heart or lung problem was being explored.

- During his time in the ED, Richard was not seen by a consultant but by an advanced care practitioner and a foundation year two (FY2) doctor. The FY2 doctor discussed the case with, and received advice from, a consultant.

- There was a delay in escalation of the case of an apparently well patient with a history of chest pain but without a clear diagnosis.

- A chest X-ray taken in the ED was incorrectly interpreted as normal. A chest X-ray is not a suitable investigation for detecting acute AD.

- The current Royal College of Emergency Medicine standards for management of radiology results were complied with.

- The delay in this case - of around four hours in the hospital - before reaching the diagnosis of acute AD is not unusual.

- Once the diagnosis was made, there was a further wait of over an hour for a formal report of the CTA scan before the patient could be referred to the specialist centre.

- Once referred to the specialist centre, the patient was immediately accepted and the ambulance departed within an hour.

- Immediate measures to control blood pressure and heart rate in patients with diagnosed acute AD are recommended. These measures were considered prior to Richard's transfer but were ruled out to save the time needed to institute them and to avoid the requirement for a medical escort.

Findings from the wider investigation

- The investigation was unable to discover national data which would allow an accurate understanding of the incidence and patient outcomes for acute AD in England.

- Analysis of hospital activity, other national data and published literature suggest acute AD may occur in around 4.5 per 100,000 of the population per year (approximately 2,500 cases per year in England). Around 20% of patients with acute AD die before reaching any hospital and 50% die before reaching a specialist centre.

- Acute AD is a rare cause of chest pain, particularly in comparison to acute myocardial infarction. Staff in non-specialist hospitals may be unfamiliar with the condition and its presentation, as it is seen relatively infrequently and symptoms can vary or be confusing.

- A delay in diagnosis of acute AD occurs in around 16-40% of cases and is more likely if the patient walks in to the hospital or a cardiac cause for chest pain is initially suspected.

- Accuracy of interpretation of chest X-rays is improved when reporting is carried out by expert radiologists. Early availability of expert chest X-ray interpretation may improve the ability to make accurate time-critical treatment decisions in the ED.

- A definitive diagnosis of acute AD can only be made by using specific imaging techniques (usually a CTA).

- Acute AD is one of a number of low-frequency, high-risk conditions which are recognised as more likely to be missed in the ED.

- Strategies are available which, if employed, would reduce delay in recognition of acute AD both in the ED and in pre-hospital care settings.

HSIB MAKES THE FOLLOWING SAFETY RECOMMENDATIONS

Safety recommendation R/2020/066:
It is recommended that the Manchester Triage International Reference Group considers the addition of *'aortic pain'* to the Manchester Triage System as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

Safety recommendation R/2020/067:
It is recommended that the Royal College of Emergency Medicine, together with the Royal College of Radiologists, develops, deploys and evaluates a national evidence-based process to detect and manage patients with acute aortic dissection presenting to emergency departments. The process should form part of a wider strategy for managing non-cardiac chest pain in the emergency department.

HSIB MAKES THE FOLLOWING SAFETY OBSERVATIONS

Safety observation O/2020/053:
There is a lack of detailed and accurate data regarding the incidence and patient outcomes for acute aortic dissection in England, particularly for those patients who do not reach a specialist treatment centre alive. Such data would assist in understanding the true scale of the problem and where any interventions might be directed.

Safety observation O/2020/054:
It would be beneficial if the providers of emergency department triage systems were to consider the addition of *'aortic pain'* as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

Safety observation O/2020/055:
Current recommendations for all patients with acute aortic dissection specify immediate measures to control blood pressure and heart rate. Non-specialist hospitals which may dispatch these patients to specialist centres might wish to review their guidance and instructions to staff in this respect. Specialist centres accepting patients with this and other life-threatening conditions could consider developing clear instructions for dispatching hospitals regarding preparation and transfer of patients, in line with best practice.

HSIB NOTES THE FOLLOWING SAFETY ACTION

Safety action A/2020/019:
In release 18, NHS Digital has amended the content of the NHS Pathways algorithm used for telephone triage of patients, to help improve recognition of chest pain likely to be associated with acute aortic dissection.

CONTENTS

1 BACKGROUND AND CONTEXT

1.1   The aorta is the largest artery in the body, carrying oxygenated blood from the heart to be distributed to all parts of the body. The aorta is a muscular tube approximately 3cm in diameter, which arises from the main pumping chamber of the heart (the left ventricle). The aorta ascends from the left ventricle towards the head for about 5cm, before curving round as the aortic arch and descending, close to the spine, through the chest and into the abdomen, where it divides at around the level of the hips, into the common iliac arteries (Figure 1).

1.2   A number of important vessels branch off the arch of the aorta:

A   the coronary arteries (which supply blood to the heart muscle itself) arise close to the origin of the aorta

and the three main vessels which supply blood to the head and arms:

B   the brachiocephalic artery (supplying the right arm and right side of the head)

C   the left common carotid artery (supplying the left side of the head)

D   the left subclavian artery (supplying the left arm).

1.3   The abdominal aorta is the part below the diaphragm, as distinct from the thoracic aorta which is the part above the diaphragm. The abdominal aorta has branches which supply blood to the abdominal organs - particularly the kidneys and gut - and to the spinal cord.

1.4   As a result of disease, the layers of the wall of the aorta can split (a dissection) or the aorta can distend (an aneurysm). Either of these may result in rupture of the aorta, which is frequently fatal. In contrast to dissections, aortic aneurysms are more common and usually develop gradually over time, with patients often having no symptoms for many months or years.

1.5   The wall of the aorta is made up of three layers. Aortic dissection (AD) occurs when the innermost layer tears, allowing blood to flow at high pressure into a new false channel
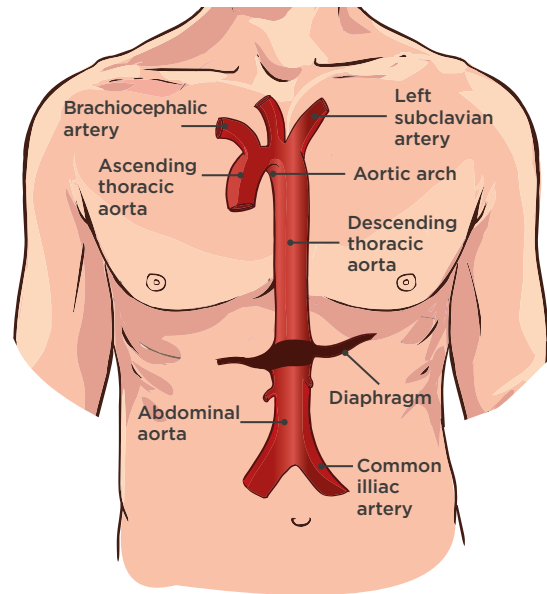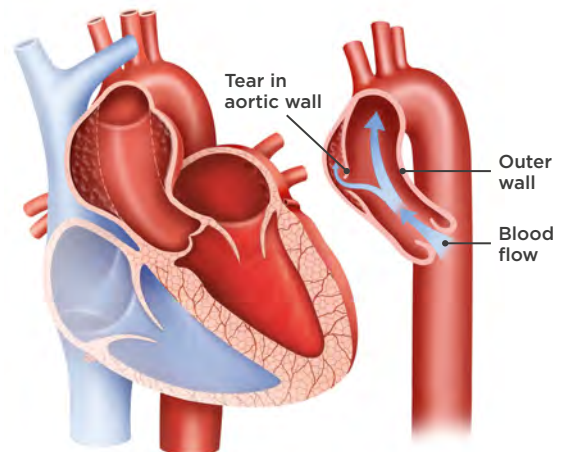
FIG 1   THE AORTA

FIG 2   THE MECHANISM OF AORTIC DISSECTION

between the layers of the wall, forcing them apart (Figure 2 (Harvard Health Publishing 2010)). A blood clot may form or blood may collect in the aortic wall (respectively called a mural thrombus or intramural haematoma). Over hours or longer periods, the outer wall of the aorta may distend and can then rupture, usually with fatal consequences.

1.6   AD typically occurs in men older than 50 years of age and the risk is increased by a number of factors affecting the vascular system (the blood vessels) as a whole, such as high blood pressure, smoking, atherosclerosis (hardening of the arteries) and inherited connective tissue disorders[1] such as Marfan or Ehlers-Danlos syndromes.

[1] Disorders of the materials which form the framework of the body's organs and structures.

1.7 Acute AD is the initial tearing of the aorta which, if left untreated, is usually fatal within hours. However, it may become a relatively stable chronic (long-term) condition.

1.8 For any medical condition, a combination of symptoms (what the patient describes), signs (what the practitioner finds on examining the patient) and investigations (tests) is used to reach a diagnosis. These may also be collectively referred to as the *'presentation'* of a condition.

1.9 The most frequent symptom of acute AD, experienced by up to 85% of patients, is the sudden onset of severe chest and/or back pain, often described as *'tearing'* in character, together with vomiting, sweating, and faintness. The location of the pain can change if the dissection extends along the aorta.

1.10 Depending on its severity, location and extent, the dissection may affect the blood supply to branches of the aorta, causing further symptoms and signs. Disruption of the blood supply can affect the brain, heart, kidneys and gut, even without complete rupture of the aorta.

1.11 Because the location of the dissection within the aorta is so important in determining the effects, AD is most often described according to classifications based on anatomical features.

1.12 In the Stanford classification, referred to in this report:

• type A involves the ascending aorta

• type B involves only the aorta beyond the left subclavian artery.

1.13 Acute AD is one of a small group of serious, painful and potentially life-threatening abnormalities of the aorta which comprise acute aortic syndrome (AAS), a term used later in this report. The other conditions include intramural thrombus and penetrating atherosclerotic aortic ulcer.

1.14 A comprehensive review of aortic disease was published by the European Society of Cardiology (ESC) in 2014 (Erbel et al. 2014).

2 THE REFERENCE EVENT

2.1 Richard was a fit 54-year-old man who regularly attended the gym, where he would carry out cardiovascular and weight training. In his 20s he had experienced paroxysmal atrial fibrillation (an intermittent abnormal heart rhythm), which still occurred occasionally, but he was no longer on any treatment.

2.2 At around 18:00 hours on the day of the event, Richard was lifting weights in the gym when he experienced a sudden central chest pain, accompanied by nausea and feeling faint. He ended his gym session and returned home. His partner described him as looking *"awful"* and said that, by the time Richard got home, the pain had moved to his upper back, between the shoulder blades.

2.3 At 18:40 hours Richard called the NHS 111 service. He described having been at the gym and experiencing chest pain while lifting *"quite a heavy weight"* then, having put the weight down, feeling *"quite out of breath for a little while"* with pain in his left arm. He had sat down, feeling light-headed, and noted that his heart rhythm was irregular for about five minutes. He reported that it had now returned to normal and he only had a faint pain in his chest.

2.4 Richard said he had never experienced anything similar before and that, although he initially felt that he may have pulled a muscle *"it's clearly not anything like that"*.

2.5 The call handler carried out an assessment using a series of questions, which included asking about the nature of the chest pain. Richard said that the pain had been between his back and his chest on the left side but had subsided after about five minutes.

2.6 Richard was asked about the severity of the pain and whether it was like a sudden agonising, ripping or tearing pain. He replied that it was severe for no more than about 15-20 seconds and that he had then sat down; however, he did not comment on the prompts as to the nature of the pain. He subsequently agreed that the pain felt like crushing, aching, or a tight band.

2.7 The call handler asked Richard whether he had ever had a heart attack or had been diagnosed with an aortic aneurysm or Marfan syndrome, which he said he had not.

2.8 The call handler advised that, based on what Richard had described, she would like to send an ambulance. The call handler advised Richard to take 300mg of aspirin and to call 999 if his symptoms became worse or he had any concerns.

2.9 An ambulance was dispatched, crewed by a paramedic (PM1) and a year one student paramedic (PM2) who was acting as the *'attending'* crew member, primarily responsible for patient care.

2.10 At 19:04 hours the ambulance arrived at Richard's home. PM2 took a medical history from Richard and examined him. The history records his pain score when examined as 0.5/10, but that the pain experienced in the gym had been felt in the left arm and back and rated as 7.5/10[2].

2.11 PM2 recalled that Richard was a little out of breath and clammy but did not think this unusual as he was just back from the gym. The examination included a check for radial artery pulses (at the wrist) in both arms - which were recorded as strong on both sides - and measurements of the blood pressure (BP) in each arm, which were taken 19 minutes apart. The BP readings were similar (the first was 127/61mmHg[3] and the second 114/84mmHg; the side of each is not recorded). PM2 stated that such bilateral measurements were standard practice for the ambulance service in cases of chest pain, together with feeling the abdomen for pulsating masses, to assist in detecting an aortic aneurysm. In this case, both tests were normal and the record states '[symbol for no] *AAA evidence'*. (AAA is an abbreviation for abdominal aortic aneurysm). The record also states that Richard's electrocardiogram (ECG) recording showed evidence of occasional premature beats and enlargement of the heart.

2.12 The crew concurred that *"everything pointed to muscular pain"*, but advised that, in view of the chest pain and the possibility that it might be an acute myocardial infarction (AMI or *'heart attack'*), they should take Richard to hospital for blood tests. PM2 said that Richard was not in

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2 Patients are commonly asked to describe the severity of their pain on a scale from 0 to 10, where 0 is no pain, and 10 is the worst pain imaginable.
3 Pressure expressed in millimetres of mercury.

pain at the time and that, as he was hungry and there were no concerns, he was allowed to eat some pasta before walking to the ambulance.

2.13 Richard was taken to the emergency department (ED) at a nearby non-specialist acute hospital (AH1), arriving at 20:04 hours. His partner followed by car. He was registered by the ED at 20:12 hours and then waited in the waiting area.

2.14 At 20:46 hours triage was carried out by the ED sister (EDS), who was working as the triage nurse. Triage is a process used to determine the urgency with which each patient needs to be seen. At the time of the reference event, EDS had worked in the AH1 ED for 15 years, and previously in other emergency departments.

2.15 Although EDS said at interview that she did not recall Richard's arrival by ambulance or receiving a handover from the crew, she remembered him, stating *"I took one look at him and thought he doesn't look well"* because of his colour and the way he was sitting, appearing to be in significant pain. Although EDS felt from the history that the pain could be muscular in origin (a muscle tear) and despite what she recalled as unremarkable observations[4], she remained concerned.

2.16 The triage note by EDS states that Richard's chest pain had now subsided to a dull ache, that his heart rate varied from 49bpm[5] to 128bpm but that he had a history of arrhythmia (irregular heartbeat). Richard's pain score was recorded as 1/10.

2.17 The ED was using an electronic version of the Manchester Triage System (MTS), which uses a decision-making flow chart or algorithm to determine the priority to be assigned to each patient. Priorities range from one (highest) to five (lowest). EDS entered the *'presenting complaint'* of chest pain, together with the other observations into the electronic system, which assigned a priority score of two, indicating that Richard should be seen within 10 minutes. The score was recorded at 20:49 hours. EDS arranged for Richard to be moved immediately to a low dependency cubicle and asked a staff nurse (EDSN) to organise tests according to the normal practice of the department.

2.18 EDSN had over seven years nursing experience and was one of two nurses working in the low-dependency cubicle area. Her role was to carry out observations and treatments and to alert other staff to any concerns about patients.

2.19 EDSN recalled that Richard walked in looking pale. EDSN said that EDS had described Richard's history of experiencing chest pain in the gym and explained that the likely origin of his pain was muscular, but that in view of his history of arrhythmia he needed an ECG. She sat him in a cubicle and organised blood tests and an ECG. A cannula[6] was inserted and blood was taken for tests at 21:01 hours (full blood count, urea, creatinine, electrolytes, glucose, PT, APTT, CRP, LFTs, cholesterol, bone profile and troponin T – see Appendix 2 for an explanation of blood tests).

2.20 EDSN asked a doctor to check the ECG, which had been recorded at 21:41 hours and which was normal.

2.21 At around 21:20 hours, Richard's care was taken over by an advanced care practitioner (EDACP). Advanced care practitioners in the ED are specially trained nurses or paramedics who work across the department and who, with appropriate supervision, are able to see all patients who present to the department with undifferentiated conditions (those without a known diagnosis) (The College of Emergency Medicine 2015). EDACP was a registered nurse who had 22 years experience at the time of the reference event, but less than a year's experience of working in the ED.

2.22 There was no handover from EDS to EDACP, who *'picked up'* Richard's case via the electronic patient board, relying on the triage note for information. The electronic patient board is a computer screen showing a list of the names of patients in the ED together with a range of other information for each. EDACP said that if there were particular concerns about a patient, the triage team would normally speak to the nurse working in the cubicle area directly, and the cubicle nurse could also speak to the triage team if required.

2.23 EDACP took a detailed history and examined Richard. His note included a description by

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Richard of the onset of chest pain lasting 10-15 seconds in the gym while lifting weights above his head and that he subsequently felt unwell, light-headed and could feel his heartbeat.

2.24 He noted that Richard *'looks well'* and said at interview that he was fully conscious and alert, was not in any discomfort and *"did not appear to be compromised in any way or in cardiovascular shock"*. The record states that Richard complained of a sensation in the chest *'as if been coughing excessively'* and some pain in his right shoulder. A Wells score (a set of clinical criteria for prediction of pulmonary embolus[7] (PE) (National Institute for Health and Clinical Excellence 2012)) was calculated as zero, which did not suggest the presence of a PE. Although the patient looked well and a musculoskeletal origin for the pain seemed likely, EDACP was unable to reproduce the pain by palpation (hand pressure) or by asking Richard to perform various movements. However, EDACP *"wasn't satisfied"* with musculoskeletal pain as a diagnosis and remained concerned because the pain could not be reproduced and Richard was saying that he didn't feel well.

2.25 Other observations were unremarkable, but blood test results became available, including a raised white cell count (which occurs when there is an infection or other inflammatory process). EDACP requested a chest X-ray and, after discussion with a registrar, a D-dimer blood test. (A raised D-dimer level indicates increased clotting activity in the blood, which may be associated with a PE).

2.26 EDACP's clerking note at 21:21 hours recorded a differential diagnosis of musculoskeletal pain, chest infection or cardiac chest pain. EDACP then handed Richard's care to a foundation year 2 doctor (FY2) and ended his shift. He said that he believed he handed over, as was his usual practice, by a face-to-face briefing conducted at the computer terminal with the help of his electronic notes.

2.27 FY2 was in her second year after qualifying and had been working in the ED for less than a week at the time of the event. She recalled receiving a verbal handover from EDACP prior to him finishing his shift, in which he described

the history of the patient experiencing chest pain in the gym and his belief that the pain was probably of musculoskeletal origin. FY2 said that EDACP had asked her to follow up the results of the chest X-ray and the remaining blood test results and had been of the opinion that the patient could be sent home if these were normal.

2.28 At 22:48 hours, FY2 added a note following the handover which recorded *'nothing obvious abnormal'* seen on the chest X-ray. The X-ray was reported the next day by a radiologist as showing enlargement of the heart and widening of the mediastinum[8]. FY2 also recorded the abnormal results of two blood tests: troponin T 30ng/l[9] (normal range 0-14), and D-dimers > 3000ng/ml (normal range 0-230).

2.29 FY2's record of her review of Richard's case noted only negative findings relating to a possible venous thromboembolism (VTE)[10]/ PE, although she also recorded the raised D-dimer result. She described him as walking round the department, although appearing distressed *'in some way'*. She also checked his oxygen saturation[11], which was normal.

2.30 FY2 discussed the case with the emergency medicine consultant on duty (EMC). EMC had worked in the department for 18 years. EMC said at interview that, although he had tried to see Richard, he had not been able to examine him because Richard had been in the toilet at the time when he went to the cubicle.

2.31 EMC advised FY2 that, although the chest X-ray was normal, the abnormal blood results remained a cause for concern and suggested that she discuss Richard's case with the medical registrar as he would probably need to be admitted.

2.32 FY2 bleeped the medical registrar and returned to Richard to advise him of this decision. She found Richard vomiting, and his partner agreed with her that something was not right.

2.33 During his time in the ED, Richard's partner recalled him as having increasingly severe back pain, pacing around and feeling

[7] Part of a blood clot, which has broken off and lodged in a blood vessel in the lung.
[8] The central area of the chest, containing the heart, aorta and windpipe.
[9] Nanograms per litre.
[10] A blood clot in the deep veins of the legs or pelvis, which is the most common source of a PE.
[11] The level of oxygen in the blood, as a percentage of the maximum possible.

nauseous, followed by vomiting and then diarrhoea. EDSN recalled Richard walking up and down, going to the toilet to vomit and sitting on the edge of the bed in between times. Richard became increasingly pale and sweaty and complained of chest pain radiating to his back.

2.34   A note written by FY2 at 22:58 hours stated that Richard felt unwell, had back pain and had vomited in the toilet. EDSN recalled that an anti-emetic (anti-sickness drug) was given. EDSN recorded a further ECG at 23:03 hours, which FY2 recalled had also been normal.

2.35   FY2 discussed Richard's case with the medical specialist registrar (MSpR), who accepted the handover of care. MSpR was a trainee doctor in her second year as a registrar (sixth year after qualification), and in her first year of specialist training in general medicine. She had worked at AH1 for eight months.

2.36   MSpR told FY2 that she had previous experience of a similar case and was concerned that this might be an aortic dissection (AD). MSpR said that she would assess Richard in the ED, and asked FY2 in the meantime to check his BP in both arms.

2.37   EDSN recalled being asked by FY2 to measure bilateral BPs, which were recorded in the notes by FY2 at 23:21 hours as a systolic[12] of 123mmHg in one arm and of 100mmHg in the other. EDSN stated that she had been taught that a difference of over 20mmHg is significant.

2.38   FY2 recalled that MSpR arrived *"fairly quickly"* and that, on learning the BP results, MSpR requested an urgent computed tomography aortogram (CTA) scan[13] at 23:27 hours.

2.39   MSpR noted that the patient looked unwell, recalling that Richard looked pale and clammy and that he was walking around and somewhat agitated. He now had flank pain on both sides and a blood pressure of *'141/8'* (probably a typographical error). A differential diagnosis of AD, thrombus (blood clot) or ischaemic bowel[14] was recorded.

2.40   Prior to the CTA scan, Richard was admitted to the acute medical unit (AMU) at around 23:30 hours, where his care was handed

over to an AMU nurse (AMUN). AMUN had qualified four years earlier and had worked at AH1 for just over a year.

2.41   AMUN did not know who handed over Richard's care but remembered checking his medical record on the electronic patient record system and noting a very high D-dimer level (the highest she had seen). She carried out observations and a safety assessment, which allows patients to be allocated into a low or high-risk group for nursing care. She described Richard as having nausea and vomiting and being given further anti-emetic medication.

2.42   Richard's partner recalled that he waited on the ward for about 30 minutes before the CTA scan, which was carried out at 00:01 hours. MSpR was present and recognised the dissection together with the radiographer, who immediately sent the images to the team at the regional cardiothoracic centre (RCC) - the hospital providing specialist cardiothoracic (heart and chest) services for the area.

2.43   Diagnostic images are normally stored and shared electronically within and between organisations using a system known as PACS (picture archiving and communication system). During the daytime, a radiologist on site would normally read diagnostic images, but a remote radiology reporting centre was used by AH1 for out-of-hours work. PACS allows this process to occur without delay. As MSpR needed a formal report before the patient could be referred to the RCC, she telephoned the reporting centre to expedite the process. The radiologist at the reporting centre was looking at the scan when she called, and confirmed the diagnosis.

2.44   The CTA scan was formally reported at 01:06 hours as showing a Stanford type A AD, with the dissection flap extending to the right common iliac artery and the right brachiocephalic artery (that is, along most of the length of the aorta – see Figure 1).

2.45   MSpR called the cardiothoracic registrar at the RCC, who had already viewed the CTA images. The registrar requested that the patient be sent to the RCC immediately by *'blue light'* ambulance. MSpR said that they would normally send a doctor with the patient, which

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[12] The upper blood pressure measurement, indicating the pressure as the heart contracts.
[13] A CT scan which uses an intravenous injection of a compound to highlight the blood vessels, including the aorta.
[14] A section of the bowel which has an inadequate blood supply.

she felt was appropriate in this case. The RCC registrar responded that this would be ideal and that an arterial line[15] should be inserted but not to do this if it would cause delay.

2.46 At 01:23 hours MSpR recorded the result of the CTA, that the cardiothoracic team at the RCC had been contacted, and that a blue light transfer was required.

2.47 MSpR called the AH1 intensive therapy unit (ITU) to request an escort for the transfer. She also called ambulance control at 01:26 hours to request an emergency ambulance as soon as possible. She recalled that the ITU senior house officer (ITUSHO) and registrar (ITUReg) came down to the AMU[16].

2.48 ITUReg had qualified five years previously and was completing his third year as a specialist trainee in anaesthetics. His role on that day was primarily to cover obstetric anaesthesia and to assist in other areas, particularly in ITU and the ED, reporting to the consultant on call for theatres. ITU cover was primarily by the ITU SHO, backed up by the ITU consultant (ITUCons).

2.49 ITUReg was alerted to the situation by ITUSHO, who asked for advice on arranging the transfer as he was new to AH1. ITUReg advised ITUSHO to contact ITUCons who was at home and would also need to come in to cover the absence of ITUReg if he accompanied Richard.

2.50 ITUCons was a consultant anaesthetist who also undertook intensive care and had worked at AH1 for 12 years. She was woken from sleep to be advised of the case. ITUCons believed the best course of action was to transfer without delaying for any form of preparation, describing a mortality[17] of 10% per hour for this condition. She said at interview that an escort in this case would not have improved the patient's outcome and that this decision would not have been any different during the day when more staff were available. However, she felt that some time might have been saved if Richard had returned to the ED after the CTA scan.

2.51 ITUCons recalled a similar case a month earlier of a patient who had been successfully transferred without special preparation and had survived. She recognised that ITUSHO was the same person who had been involved in the care of the previous case, and so was familiar with the details of similar discussions which had occurred about that case.

2.52 ITUCons also told the investigation that AH1 transferred all patients with ruptured abdominal aortic aneurysm without escort, this being a policy agreed with the local network of vascular surgeons because there was no additional survival benefit from the presence of an escort.

2.53 ITUReg recognised the need to expedite Richard's transfer and was expecting to accompany the patient. He picked up the transfer trolley from the ITU and took it to the AMU. The trolley can be used in front line ambulance vehicles and provides additional equipment for high-risk patients.

2.54 ITUReg stated that there was guidance within the region for transfer of trauma patients but that, in general, the type of escort would depend on the *'level'* [of acuity] of the patient (severity and anticipated needs). He did not examine Richard as he was under the care of MSpR but saw his role as helping to facilitate the transfer.

2.55 At around this time, the RCC cardiothoracic registrar called MSpR again to encourage the AH1 team to get Richard to the RCC as soon as possible and advised that, because there were no beds in the hospital, the patient should be taken straight to theatre on arrival. ITUReg told the investigation that this would be the normal procedure for this condition in any case.

2.56 The ambulance arrived at 01:48 hours (22 minutes after the request had been made) and MSpR recalled that it *"took longer than we were comfortable with"*. While waiting, MSpR took the opportunity to explain the serious nature of the situation to Richard and his partner, including what could potentially happen during the transfer.

2.57 Although Richard didn't seem to be in much pain, MSpR was concerned about his high BP, which might be exacerbated by anxiety and vomiting, increasing the risk of aortic rupture.

[15] A cannula inserted into an artery (usually at the wrist), allowing direct and accurate blood pressure measurement.
[16] The position of SHO (senior house officer) has now been replaced by the foundation year 2 (FY2) or specialty trainee (ST1-2) grades, although the term SHO remains in use. Likewise, the term registrar will refer to a doctor undertaking further specialist training (ST3-8).
[17] Mortality when used in its medical sense refers to death rate, for example the percentage of patients who die from a condition per year.

2.58　MSpR said that this concern had been shared by ITUReg, who had previously accompanied a consultant on a similar transfer to control the patient's BP. He disagreed with the decision of ITUCons and wanted to take steps to reduce the BP but was not willing to call ITUCons again to suggest this.

2.59　At interview, ITUReg recalled a conversation with MSpR regarding priorities of care and had started to make some preparations. However, ITUSHO had informed him that ITUCons had decided that, as the ambulance would arrive before the necessary preparations could be made or ITUCons could get there to provide cover, the transfer would be undertaken without further preparations or a doctor escort. The preparations would have involved setting up an arterial line for direct measurement of Richard's BP and infusions of drugs to control the BP. Instead, ITUReg went to the ED to meet the ambulance paramedics and escort them to the AMU.

2.60　ITUReg briefed the paramedics on Richard's condition, gave them advice on the procedure at the RCC and asked that they drive carefully over any rough ground.

2.61　Richard was given paracetamol and an anti-emetic drug. Although she might have considered a stronger analgesic (pain-killer), such as morphine, MSpR felt that Richard was more anxious than in pain. MSpR said she believed that Richard's systolic BP was 160mmHg at the time the ambulance departed but was not sure if anyone had raised this issue with ITUCons.

2.62　ITUSHO handed the patient over to the ambulance crew, who departed with the patient and his partner at 01:57 hours.

2.63　Subsequent events are summarised below and are described in more detail in the report of the first part of the HSIB investigation (Healthcare Safety Investigation Branch, Transfer of critically ill adults 2019b).

Summary of subsequent events

2.64　Approximately 12 minutes into the transfer, Richard suffered a respiratory arrest (his normal breathing stopped) from which he initially recovered, but almost immediately went into cardiac arrest (his heart stopped producing an effective blood flow). The ambulance crew began resuscitation and contacted the control centre for further assistance. A senior paramedic in a rapid response vehicle and a paramedic officer with additional resuscitation equipment met the crew en-route.

2.65　After discussion with the control room, the crew decided to divert to the emergency department of a large specialist acute hospital (AH2) which was close to their route, to obtain blood for the patient. The crew contacted the control centre and asked the dispatcher to pre-alert the AH2 ED that they were coming.

2.66　Upon arrival at the AH2 ED, a message from the RCC was passed to the crew to immediately proceed to the RCC so that Richard could undergo urgent surgery. Richard was not taken out of the ambulance, which immediately departed for the RCC. During this phase of the transfer, contact was made between the ambulance crew and the RCC. When the RCC was informed that Richard had been in cardiac arrest for 32 minutes, they confirmed that there was nothing that could be done to save him.

2.67　The crew returned to the AH2 ED but attempts to resuscitate Richard were unsuccessful and he was pronounced dead at 03:15 hours.

2.68　A summary of events and times is included at Appendix 1.

3 INVOLVEMENT OF THE HEALTHCARE SAFETY INVESTIGATION BRANCH

3.1 Notification of the reference event and decision to investigate

3.1.1 The Healthcare Safety Investigation Branch (HSIB) was notified by an ambulance service of a 54-year-old man who had died from a thoracic aortic dissection (AD) during transfer from a local hospital to a specialist cardiothoracic centre for life saving surgery. The initial information provided to HSIB identified possible safety issues regarding the preparation of the patient for transfer and the subsequent transfer itself.

3.1.2 Following preliminary information gathering, HSIB concluded that the safety issues represented by this event met the criteria for investigation, which was authorised by the HSIB Chief Investigator.

3.2 Evidence gathering and methods

3.2.1 Methods used in this investigation included:

- review of patient clinical records, hospital policies and guidelines in place at the acute hospital where the patient was first taken

- review of the audio recording of the call made by the patient to the NHS 111 service

- semi-structured interviews with the patient's partner, staff at the acute hospital where the patient was first taken and with one of the two ambulance paramedics who conveyed him there

- a review of the internal incident report by the acute hospital trust

- a review of literature relating to AD and decision making

- discussions with, and written advice from, expert subject matter advisors regarding AD, emergency department practice, decision making and human factors[18]

- correspondence with a representative of a group campaigning for patients with AD and their families.

[18] Human factors is the science which seeks to optimise human performance and wellbeing by understanding the behaviour of individuals and their interactions with each other and with their environment.

4 FINDINGS AND ANALYSIS

4.1 The epidemiology and outcomes of acute aortic dissection

4.1.1 National incidence and surgical data

4.1.1.1 The investigation did not discover detailed national data which would allow an accurate understanding of the incidence[19] and patient outcomes for acute aortic dissection (AD) in England.

4.1.1.2 The NHS in England collects a large amount of data on hospital activity which are published as Hospital Episode Statistics (HES), containing details of all admissions, Emergency Department (ED) attendances and outpatient appointments at NHS hospitals in England.

4.1.1.3 In 2017-18 there were 2,581 finished consultant episodes[20], 1,638 admissions, and 1,182 emergency admissions coded as *'dissection of aorta [any part]'* (NHS Digital 2018a). Office for National Statistics (ONS) data on deaths records 1,345 deaths with the same code in 2017 (Office for National Statistics). It should be noted that the figures for finished consultant episodes and admissions may count the same patient more than once. However, this is less likely to apply to the number of emergency admissions which may be more useful as an indicator of the incidence of acute AD.

4.1.1.4 HES data for procedures and interventions for the same period include 690 emergency procedures for aortic repair (aneurysm or dissection) excluding mention of the abdominal aorta (NHS Digital 2018b) . These include 325 specifically indicating ascending aorta and 129 indicating thoracic aorta. Therefore, at least 454 emergency repairs were carried out to the thoracic aorta, and potentially up to 690.

4.1.1.5 The National Vascular Registry and the Society for Cardiothoracic Surgery also collect data on surgery for these conditions.

4.1.1.6 Apart from data generated by published studies, there does not appear to be more detailed national statistical information about patients with acute AD before they reach a specialist centre, including encounters with pre-hospital and ED services.

4.1.2 Incidence data from published research

4.1.2.1 A review of published literature found a number of reports of interest, including the following.

4.1.2.2 A review of over 14,000 cases from the Swedish national healthcare registers from 1987 to 2002 (covering a population of approximately 8.7 million) quotes the overall incidence of diagnosed thoracic aortic disease (dissection or aneurysm) as 10.2 per 100,000 of population per year. Of these, 31% were dissections – that is, an incidence of 3 per 100,000 per year (Olsson et al. 2006).

4.1.2.3 The incidence was nearly double in men compared to women, increased with age and also increased over the 15 year period. In 22% of cases, the patient did not reach hospital alive and, of those that did, 34% died within 30 days (this figure is referred to as the 30 day mortality).

4.1.2.4 A more recent review of data for the population of Ontario, Canada (approximately 13 million) between 2002 and 2014, found an overall incidence of thoracic AD of 4.6 per 100,000 of population per year. Of these, 38% were type A and the incidence of both thoracic dissections and aneurysms increased over the study period, although outcomes improved (McClure et al. 2018).

4.1.2.5 There are also a number of other, non-UK, studies based on much smaller, localised populations which may not represent the national demographic but are relevant as their data is often quoted elsewhere (Mészáros et al. 2000; Clouse et al. 2004).

4.1.2.6 The Oxford Vascular Study (OxVasc) has been collecting data since 2002 on patients with vascular diseases registered with eight general practices in Oxfordshire, representing a population of around 93,000. Between 2002 and 2012, there were 173 aortic events, of which 52 were thoraco-abdominal dissections – an incidence of 6 per 100,000

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[19] The number of new cases or events over a period of time.
[20] The time a patient spends in the care of one consultant in one health-care provider. A single admission may include more than one consultant episode.

of population per year (Howard et al. 2013). Of the 173 cases, 18 patients (35%) died at home and a further five (10%) were dead on arrival at hospital; 71% of dissections were type A and 29% type B, with a 30-day mortality of 47% in those patients with type A dissections who survived to specialist hospital admission (Howard et al. 2013).

4.1.2.7   The authors of the study have also combined the incidence rates found in their study with ONS national population data to predict that annual acute AD events in the UK will increase from 3,892 in 2010 to as many as 6,893 in 2050 (Howard et al. 2014).

4.1.2.8   The OxVasc study has now completed its 15th year and will report again in due course. Preliminary results indicate that the incidence of acute AD remains similar (6 per 100,000 of population per year) or is possibly increasing slightly. Around 50% of patients die before reaching a tertiary centre and 15-25% of patients who undergo surgery die during the procedure or within 30 days afterwards (this is referred to as surgical mortality) (Howard 2019).

4.1.3   Risk factors and outcomes

4.1.3.1   A significant source of information on acute AD is the collection of publications based on data held by the International Registry of Acute Aortic Dissection (IRAD). IRAD is a consortium of 30 specialist centres in 11 countries (none in the UK) which currently has data on 3800 cases of acute AD (as quoted on the IRAD website [iradonline.org], accessed in November 2019.

4.1.3.2   There are a number of published papers based on IRAD data (Hagan et al. 2000; Pape et al. 2015; Evangelista et al. 2016) but, because IRAD only includes patients who reach designated tertiary referral centres alive, the database cannot be used to understand overall population incidence. It does, however, provide useful information on the risk factors, presentation, management and outcome of patients with acute AD.

4.1.3.3   In a 2016 review of IRAD data, the most common risk factor identified was high

blood pressure (hypertension) (72%), with smaller numbers thought to be related to Marfan syndrome (5%) and iatrogenic[21] causes (4%). Younger patients (less than 40 years of age) were less likely to have a history of hypertension (34%) or atherosclerosis[22] (1%) but more likely to have Marfan syndrome or a bicuspid aortic valve[23] (59%) (Evangelista et al. 2016).

4.1.3.4   The finding of hypertension as the most common risk factor for acute AD is replicated in the OxVasc data published by Howard et al, which also found that control of blood pressure was poor in patients prior to dissection, despite 67% of patients being on medication to reduce blood pressure. Poorly controlled hypertension as the most significant risk factor remains a key finding from the OxVasc data after 15 years.

4.1.3.5   IRAD data show that the majority of patients presenting with type A acute AD were treated surgically (86%), whereas the majority of patients with type B acute AD were treated medically (63%). This latter figure has decreased in the last 20 years, as the use of endovascular[24] treatments has become more common.

4.1.3.6   Death in hospital from acute AD has dropped significantly, from 31% to 22%, mainly due to a decline in surgical mortality from 25% to 18%.

4.1.3.7   Although rare, late pregnancy and the puerperium[25] are associated with a 25-fold increase in risk of acute AD. The outcome is frequently fatal (Nasiell and Lindqvist 2010) and diagnosis is often delayed (MBRRACE-UK 2016).

4.1.4   Association between acute AD and intense exercise

4.1.4.1   There have been sporadic reports in the literature of acute AD occurring during bouts of intense exercise, particularly weightlifting. A 2007 study identified 31 patients in whom acute AD occurred in this context; all but one were males. The authors found that moderate aortic dilatation (distension) confers vulnerability to exertion-related AD (Hatzaras et al. 2007).

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[21] Iatrogenic refers to harm caused as a result of medical care.
[22] A common condition in which arteries are narrowed by fatty deposits formed on the inner walls, which may obstruct blood flow by breaking off or by triggering blood clots.
[23] An aortic valve which only has two valve leaflets (flaps) rather than the usual three.
[24] Where the aortic repair operation is carried out using instruments inserted through an artery (usually in the groin).
[25] The period of about six weeks after childbirth.

4.1.5 Summary of evidence for incidence and outcomes of acute AD

4.1.5.1 Acute AD is a life-threatening emergency, and the number of cases is likely to increase in the future as the population ages.

4.1.5.2 There is a need for accurate epidemiological data for England regarding acute AD, particularly covering the period before admission to any hospital and prior to admission to a specialist centre. This would allow an understanding of the true scale of the problem and where any interventions might be directed.

4.1.5.3 From the available information described above, it is likely that the annual incidence of acute AD is between 4 and 5 per 100,000 of population per year – that is, around 2,500 cases per year in England (based on 4.5 per 100,000 population). The most common risk factor is poorly controlled hypertension.

4.1.5.4 The prognosis is grave, with perhaps 50% of patients dying before reaching a tertiary centre, and around 20-30% dying before reaching any hospital. 30-day mortality remains high, between 15-25%. This estimate would be consistent with the HES data above.

HSIB MAKES THE FOLLOWING SAFETY OBSERVATION:

Safety observation O/2020/053:
There is a lack of detailed and accurate data regarding the incidence and patient outcomes for acute aortic dissection in England, particularly for those patients who do not reach a specialist treatment centre alive. Such data would assist in understanding the true scale of the problem and where any interventions might be directed.

4.2 How is acute AD diagnosed and treated?

4.2.1 What is ideally required, particularly for life-threatening conditions, is a set of symptoms, signs or investigations which will, individually or in combination, rapidly and reliably rule in or rule out the diagnosis. The accuracy of a test in ruling in a condition when it is present is referred to as its *'sensitivity'*, and the ability of a test to reliably rule out a condition is referred to as its *'specificity'*. Both terms are used below.

4.2.2 The role of signs and symptoms in the diagnosis of acute AD

4.2.2.1 The clinical effects of acute AD will depend on the location, severity and extent of the dissection. In addition to the pain caused by the initial aortic tear, the symptoms and signs reflect the reduction in blood supply to the brain or spinal cord (fainting, stroke and other neurological signs), heart (myocardial ischaemia or infarction[26]), gut (abdominal pain, nausea, vomiting and diarrhoea) and kidneys. The dissection may cause physical disruption of the aortic valve, affecting its function and resulting in heart failure.

4.2.3 Pain

4.2.3.1 Pain in the chest, back or abdomen is the most frequent symptom of acute AD (in 95% of patients). Abrupt onset of severe chest and/or back pain is the most typical feature and was the single most common presenting complaint in the IRAD data (72%), which corresponds with findings in other studies. However, *'tearing, ripping or migratory'* - which have been classically taught as descriptors of the pain resulting from acute AD - were not common in the IRAD database. Chest pain was significantly more common in patients with type A acute AD (79%, versus 63% in type B dissections), whereas back pain and abdominal pain were more common in type B acute AD (64% versus 43% in type A) (Hagan et al. 2000). A review of the literature found that most patients (84%) with thoracic AD have severe pain of sudden onset (Klompas 2002). The absence of sudden pain at onset lowers the likelihood of dissection.

4.2.3.2 A small proportion of patients (6-17%) present with no pain but are more likely to have reduction of consciousness, a neurological deficit (loss of sensation or strength) or heart failure. Compared with patients who have painful acute AD, patients who have painless acute AD have a higher mortality, especially those with type B acute AD. (Park et al. 2004; Imamura et al. 2011).

4.2.4 Other symptoms and signs

4.2.4.1 Other symptoms and signs of acute AD include fainting (13%), an elevated blood

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[26] Reduction in the blood supply to the heart muscle (ischaemia), which may lead to its death (infarction).

pressure (28%), a diastolic murmur[27], symptoms of stroke or focal neurological deficits[28] (17-42%) or a clinical picture of acute abdomen[29] (6%) (Pape et al. 2015; Mészáros et al. 2000).

4.2.4.2 Pulse deficits, defined as decreased or absent carotid (neck) or peripheral (limb) pulses, were noted in several studies in around 30% of patients with type A dissection. This sign is more likely to be associated with neurologic deficits, altered mental status and low blood pressure, shock, or tamponade[30] on admission, as well as higher overall mortality rates (Bossone et al. 2002).

4.2.4.3 A difference in the systolic blood pressure in each arm is another well-known sign of AD and the presence or absence of this sign was significant in the decision-making for Richard's case.

4.2.4.4 However, although bilateral systolic blood pressure differentials greater than 20 mmHg are present in 30% of non-traumatic AD, the poor diagnostic accuracy and potential variability in measurement limits the clinical usefulness of this as a test. Pulse deficit alone may be a more useful sign (Um et al. 2018). Furthermore, 19% of the general population may have blood pressure differences between the arms, with differentials of greater than 10mmHg being present in 53% (Singer and Hollander 1996).

4.2.5 Investigations

4.2.5.1 Electrocardiogram (ECG)

4.2.5.1.1 In a review of IRAD data, the ECG in type A acute AD was normal in 31% of patients, showed non-specific ST and T wave changes[31] in 42%, ischaemic changes in 15% and evidence of acute myocardial infarction (AMI) in 5%.

4.2.6.2 Chest X-ray

4.2.6.2.1 *'Typical'* radiographic findings of type A AD include widening of the mediastinum or aortic knuckle[32]. However, the signs can be subtle and both experience and a degree of suspicion may be required to detect these changes. A review of IRAD data found that more than 20% of patients with confirmed AD lack abnormalities of the mediastinum or aortic contour on chest X-ray (Hagan et al. 2000).

4.2.6.3 Laboratory tests

4.2.6.3.1 A number of blood tests are recommended if acute AD is suspected (Erbel et al. 2014). Although there are no specific tests for acute AD, there are several experimental tests currently under investigation. There are also two tests used routinely to detect other conditions, the results of which may be abnormal in acute AD and were significant in the reference event.

4.2.6.3.2 Troponins T and I are specific cardiac structural proteins which are released if there is injury to heart muscle. A rising troponin level is routinely used to confirm a diagnosis of AMI and to allow assessment of risk. Measurement of troponin levels is also used to assist in refuting the diagnosis of AMI, particularly where characteristic ECG changes are not present. (National Institute for Health and Care Excellence 2014). Both the absolute level of troponins and the change of levels over time are important.

4.2.6.3.3 As AMI is one of the key differential diagnoses of acute chest pain, particularly in Richard's age group, serum troponin levels are likely to be measured in patients who have suffered an acute AD. As many as 23% of patients with type A acute AD may have raised troponin I levels, which may direct clinicians towards an incorrect diagnosis of AMI (Bonnefoy et al. 2005; Leitman et al. 2013). Furthermore, patients with acute AD may also actually suffer an AMI as a result of the dissection (Leitman et al. 2013).

4.2.6.3.4 D-dimers are products formed when blood clots are broken down by the body. They are normally undetectable in the blood and are produced only after a clot has formed and is in the process of being broken down.

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[27] An abnormal sound, heard through a stethoscope, produced by changes in blood flow through the heart.
[28] A problem with the nervous system which affects a specific part of the body (such as the arm) or function (such as eyesight).
[29] Severe abdominal pain, usually requiring emergency surgery, caused by acute disease of or injury to the internal organs.
[30] A collection of blood in the sac around the heart which adversely affects its function.
[31] Non-diagnostic changes in those parts of the ECG pattern which are usually abnormal in AMI.
[32] A prominence caused by the aortic arch in the outline of the mediastinum on chest X-ray.

4.2.6.3.5 A negative D-dimer result makes it very unlikely that a significant blood clot exists, but a positive result can be found in a variety of conditions. The test is frequently used when a venous thromboembolism (VTE)[33] or a pulmonary embolus (PE)[34] is suspected. Very high levels are likely to indicate significant disease of some sort (Schutte et al. 2016).

4.2.6.3.6 In the case of a patient with acute chest pain, the D-dimer level may be helpful in making a differential diagnosis (Pathak et al. 2011). A very high D-dimer level may increase suspicion of acute AD; one study found that D-dimer was markedly elevated in patients with acute AD (Suzuki et al. 2009). A result showing a low level may also be helpful; the widely used cut-off level of 500 ng/mL for ruling out a PE has also been used to rule out AD, but this may not be reliable (Suzuki et al. 2009; Li et al. 2017).

4.2.7 Imaging studies

4.2.7.1 There are three main methods currently used to image the aorta for the diagnosis of acute AD.

4.2.7.2 Computed tomography (CT) uses X-rays to produce a series of cross-sectional views that can be combined into a three-dimensional image. To detect AD, a CT aortogram (CTA) is usually performed, using an intravenous contrast injection to enhance the view of the blood vessels.

4.2.7.3 Trans-oesophageal echocardiography (TOE) uses high-frequency sound waves (ultrasound) to produce detailed images of the heart and the vessels leading to and from it. The echo transducer (the probe which emits and detects the sound waves) is attached to a thin tube which is inserted through the mouth and into the oesophagus (food pipe), which lies close to the upper chambers of the heart, resulting in clear images of the heart structures and valves.

4.2.7.4 Magnetic resonance imaging (MRI) creates 3D images from slices in a similar way to CT but uses strong magnetic fields and radio waves to produce very detailed images. CT is generally more widely available than MRI.

4.2.7.5 IRAD data showed that CTA was the initial imaging study in 69% of cases of acute AD, TOE in 25% and MRI in 4% (Moore et al. 2002).

4.2.7.6 A review of 16 studies involving a total of 1,139 patients found that all three imaging techniques (CTA, TOE and MRI) are equally reliable diagnostic tools for ruling in or ruling out AD (Shiga et al. 2006). The sensitivity and specificity was similar for each method.

4.2.7.7 The method used tended to depend on the availability of diagnostic facilities at local hospitals and the degree of emergency. Each method has advantages in specific circumstances – for example, CTA and MRI are better at assessing the extent of dissection and involvement of branch vessels (Erbel et al. 2014). CTA is widely available, relatively quick to perform and can also be used to exclude a PE.

4.2.8 Summary of the presentation and diagnosis of acute AD

4.2.8.1 Abrupt onset of severe chest and/or back pain (which may subsequently diminish) is the most frequent symptom of acute AD, occurring in over 95% of patients. Chest pain is more common in type A dissection.

4.2.8.2 Pain may occur elsewhere, such as in the abdomen, or there may be neurological symptoms or disturbance of consciousness.

4.2.8.3 A small proportion of patients present with no pain but are more likely to have disturbance of consciousness or symptoms or signs of heart failure or stroke. Pulse deficits or differences in blood pressure between the arms may occur in around a third of patients, but the latter can be present in up to a fifth of the general population.

4.2.8.4 Imaging using CTA, MRI or TOE is the only definitive diagnostic investigation for acute AD. An abnormal chest X-ray or raised D-dimer levels may be useful pointers, if present.

4.2.9 Treatment of acute AD

4.2.9.1 Treatment recommendations can be summarised as follows (Erbel et al. 2014).

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[33] A blood clot in the deep veins of the legs or pelvis.
[34] A clot which has broken off and lodged in a blood vessel in the lung.

4.2.9.2 Medical therapy to control pain, anxiety and blood pressure is essential. The main aim of this treatment is to reduce shear stress (stretching forces) on the aortic wall by reducing blood pressure and the strength of heart contractions. This is achieved using intravenous beta-blocking drugs or other agents to reduce the heart rate and lower the systolic blood pressure to 100–120 mmHg.

4.2.9.3 For type A acute AD, surgery is the treatment of choice.

4.2.9.4 Type A acute AD has a mortality of 50% within the first 48 hours if not operated on. Although surgical mortality (25%) and neurological complications (18%) remain high, surgery reduces 30-day mortality from 90% to 30%. There is still controversy over whether surgery should be performed in patients with type A acute AD who present with neurological deficits or coma.

4.2.9.5 Type B AD can often be managed medically by control of heart rate and blood pressure, but if disease progresses or other complications develop, surgery may be required. Open surgery is now relatively rare and, instead, repair of the aorta is carried out using instruments passed into the thoracic aorta through an artery in the groin. This procedure is known as TEVAR (thoracic endovascular aortic repair). TEVAR not only avoids the patient having to undergo major thoracic surgery but, because this procedure is usually performed by a vascular surgeon, the service may be available on site, which also means that the patient does not have to be transferred to a specialist centre.

4.2.9.6 For a contemporary overview and reviews of the clinical presentation, diagnosis and treatment of acute AD, see: the European Society Cardiology (ESC) guidelines (Erbel et al. 2014), those of the American Heart Association and American College of Cardiology (Hiratzka et al. 2010), BMJ Best Practice (Hicks CW, Black II JH 2018), Redfern et al (Redfern et al. 2017), Hebballi and Swanevelder (Hebballi and Swanevelder 2009) and Thrumurphy et al (Thrumurthy et al. 2011).

4.3 The reference event in the context of what is known about acute AD

4.3.1 The symptoms and signs related by Richard's partner and medical staff and as recorded in the medical notes are consistent with those described above, as are the initial investigation results of the ECG, chest X-ray, troponin I and D-dimer blood tests.

4.3.2 Of particular note is Richard's description of the sudden onset, severity and location of the pain, which had diminished to a *"faint pain"* by the time he reached home, together with feelings of faintness and shortness of breath.

4.3.3 During his time in the ED, Richard became increasingly unwell, pale and sweaty with nausea, vomiting and bilateral flank pain. He also developed a difference between the blood pressure in each arm, which was not present when the ambulance crew first attended. Given the subsequent CTA findings, this would be consistent with extension over time of an initial dissection, into the aortic arch (to the right brachiocephalic artery) and along the aorta (to the right common iliac artery), affecting the blood supply to the gut.

4.3.4 It may be relatively easy to establish this view in retrospect and with access to the relevant information in one place. However, to individual members of staff - each with their own knowledge and experience and with competing demands for their attention in the general traffic of the ED - the picture would have seemed far from clear.

4.3.5 The challenge of tracking the progression of symptoms, signs and other findings as a condition evolves during the course of a patient's stay in a busy ED, and responding to and using this information to inform a diagnosis, is a theme in another published HSIB investigation (Healthcare Safety Investigation Branch, Recognising and responding to critically ill patients 2019a).

4.3.6 The remainder of this analysis considers what might be done to help staff recognise this condition more rapidly.

4.4 Opportunities for early recognition of acute AD

4.4.1 It is estimated that around 70-80% of patients with acute AD arrive alive at a hospital emergency department. Many, if not all, will have been taken there by ambulance.

4.4.2 Ambulance service crew are therefore often the first to encounter the patient and have the opportunity to make the diagnosis; others making first contact with the patient may include primary care practitioners (such as GPs) and, in the UK, the NHS 111 service. There may also be a very small group of patients in whom AD (more likely type B) is recognised as an incidental finding during an encounter with the healthcare system for a different problem.

4.4.3 Given the serious hazard posed by acute AD and the time-critical requirement for potentially lifesaving intervention, it is desirable that the diagnosis is made as soon as possible.

4.4.4 Improved capability to recognise acute AD before hospital admission could have a significant effect in reducing mortality and morbidity (ill-health) from this condition, perhaps allowing patients to be transported directly to specialist treatment centres. Although this investigation focuses on diagnosis in the ED, the findings are likely to be relevant for the ambulance service, telephone advice networks and primary care settings.

4.5 How often is the diagnosis delayed or missed in the emergency department?

4.5.1 Although there are anecdotal reports of missed diagnosis of acute AD, there does not appear to be any systematic national data collected in the UK which would allow this question to be answered.

4.5.2 Published figures for delayed or initial mis-diagnosis of acute AD range from 16-39% of cases. In a review of 11 years of IRAD data, Harris et al found that the median[35] time from arrival in the ED to diagnosis was 4.3 hours (Harris et al. 2011). Hansen quotes a similar figure of five hours (Hansen et al. 2007).

4.5.3 A small series study found that acute AD had not been correctly diagnosed at the end of the initial ED assessment in 16% of cases, with alternative diagnoses of acute coronary syndrome (ACS)[36], other cardiovascular disease, abdominal disease and stroke being reached instead (Kurabayashi et al. 2011).

4.5.4 A review of 66 patients with AAS admitted over four years to a tertiary hospital, found that 39% had initially been misdiagnosed, resulting in an extension of the mean (average) time to correct diagnosis from 5 to 12 hours (Hansen et al. 2007). ACS was again the most common misdiagnosis and the administration of anti-thrombotic agents[37] following this diagnosis was associated with higher rates of major bleeding (38% versus 13%), heart rate and blood pressure instability (30% versus 13%), and a trend toward greater in-hospital mortality (27% versus 13%).

4.5.5 In relation to this, it should be noted that Richard was advised to take aspirin by the NHS 111 call handler. Aspirin interferes with the normal clotting process and would be usual *'first aid'* treatment for a patient with suspected AMI, but could exacerbate bleeding in acute AD.

4.6 Why the diagnosis of acute AD might be missed

4.6.1 Acute AD is a rare condition and a relatively rare cause of chest pain

4.6.1.1 In 2017/18, there were almost 15 million ED attendances in England. NHS data do not record the presenting complaint for patients attending EDs and there is no international standard classification for this. However, a study of patients attending a Finnish ED by Malmstrom et al found that 3.7% presented with chest pain and 21% with musculoskeletal symptoms or complaints (Malmström et al. 2012). In 2015, chest pain accounted for 5.3% of ED visits in the USA (National Center for Health Statistics).

4.6.1.2 Based on the estimate above, of 2,500 cases of acute AD per year, of which around 2,000 reach a hospital alive, each ED in England would expect to see an average

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[35] The middle of a range of values.
[36] A set of symptoms and signs resulting from reduced blood flow in the coronary arteries, which supply blood to the heart muscle.
[37] Drugs used to prevent blood clotting.

of 15 cases of acute AD per year. This would represent around one case of acute AD for every 400 patients presenting with chest pain.

4.6.1.3 This estimate also assumes that all patients with acute AD who reach a hospital arrive at the ED, which is probably not the case; some may be admitted by other routes or reach specialist centres directly, reducing both the frequency with which acute AD is encountered in the ED and the proportion of patients presenting with chest pain who have acute AD as the diagnosis.

4.6.2 Patients may appear well or symptoms can be variable and mimic other conditions.

4.6.2.1 Patients with acute AD can present with a range of inconsistent symptoms and signs which are more usually associated with other, more common, conditions, resulting in delayed recognition of AD. The symptoms and signs of acute AD may include fainting, low blood pressure, stroke and signs of other neurological deficits, heart failure or AMI.

4.6.2.2 The most common and constant feature of acute AD is sudden onset chest pain, but pain may be absent or felt at a different site, such as the abdomen. Patients with acute AD who have abdominal pain tend to have a delayed diagnosis and experience a higher mortality than those with more typical symptoms (28% versus 10%) (Upchurch et al. 2006).

4.6.2.3 Patients presenting without pain are more likely to have a missed or delayed diagnosis (Park et al. 2004) and the tendency for the initial pain to abate quite rapidly may falsely reassure clinical staff, as in Richard's case.

4.6.2.4 Following the initial event, patients with acute AD can appear relatively well. One study found that the foremost factor leading to diagnostic failure was perceived mildness of disease at presentation, with acute AD being undetected in 36% of patients who walked into the ED, compared to 13% of patients who arrived by ambulance. (Kurabayashi et al. 2011). Walk-in patients and those with evidence of reduced blood flow in the coronary arteries were most at risk of initial misdiagnosis (37%) (Hirata et al. 2015).

4.6.2.5 Delay was associated with initial diagnosis at a non-specialist hospital, atypical symptoms that were not sudden or did not include chest, back or any pain, or an initial suspicion of ACS or lung disease. Delay was more likely to occur in cases where the patients were female (Harris et al. 2011; Strauss et al. 2017).

4.6.2.6 Rapid diagnosis of acute AD is most likely when CT or TOE form part of diagnostic testing. In contrast, when an MRI was performed, the diagnosis was delayed, which may represent cases in which an alternative diagnosis was initially contemplated.

4.6.2.7 In short, unless characteristic chest pain is present, there are no signs or symptoms that specifically indicate the presence of acute AD and Klompas concludes that *'overall, the clinical examination is insufficiently sensitive to rule out aortic dissection given the high morbidity of missed diagnosis'* (Klompas 2002). A combination of findings may improve accuracy (Rogers et al. 2011).

4.6.2.8 Richard was on the verge of being sent home with a suspected musculoskeletal injury before the very high D-dimer result was received and his general condition began to deteriorate.

4.6.3 Knowledge of acute AD is limited

4.6.3.1 There may be a disparity between the knowledge of the symptoms and signs of acute AD by staff in specialist centres, who see more patients with this condition, compared with staff in other hospitals. The latter are more likely to have early contact but encounter patients with the condition less frequently. Staff in the non-specialist hospitals are more likely to be familiar with abdominal aortic aneurysms, which are more common.

4.6.3.2 The student paramedic (PM2) checked Richard's blood pressure and pulses in both arms, but there did not seem to be any awareness of the limited effectiveness of these checks in detecting acute AD or the importance of the history and the nature of the chest pain. There was also a 19 minute interval between the recording of the

blood pressure readings in each arm, which would have reduced its effectiveness as a diagnostic test.

4.6.3.3   Although the ED staff nurse (EDSN) had previously seen other patients with *"aneurysms"*, she said that she didn't feel Richard's presentation aroused any suspicion of this diagnosis and only became concerned once she had taken the bilateral blood pressure readings. This was also the first patient in her experience with a thoracic dissection; the others were abdominal aortic aneurysms (AAA) and had presented with abdominal pain.

4.6.3.4   The ED advanced care practitioner (EDACP) described at interview the clinical picture he would expect to see in patients with *"dissecting aortic aneurysms"*, which was quite unlike the appearance of Richard. He stated that although the subject had been covered in training, he had never seen anyone with a *"dissecting triple-A"*, but that it wasn't something that came to mind in Richard's case.

4.6.3.5   The foundation year 2 doctor (FY2) said she had no particular knowledge of the presentation of AD, but would not have considered it as a diagnosis, because Richard appeared so well.

4.6.3.6   The emergency medicine consultant (EMC) said that he was not aware of any clinical decision-making tools for recognising AD, apart from bilateral blood pressure readings and chest X-ray.

4.6.3.7   Although it is beyond the scope of this investigation, it would be useful to know how and at what stage the presentation and management of acute AD is taught during undergraduate and postgraduate training.

4.7   The functions of the emergency department

4.7.1   What is the mission of the emergency department?

4.7.1.1   According to the NHS, EDs in the UK exist to deal with genuine life-threatening emergencies (NHS 2018). In practice, they attract patients presenting with

undifferentiated conditions (without a known diagnosis) of a very wide range of urgency. EDs in England experienced around 15 million attendances in 2017-18 and, over the past 10 years, attendances at EDs in England have increased by 22% (Hospital Accident and Emergency Activity, 2017-18 - NHS Digital).

4.7.1.2   There is no published specification for EDs in England (although there is a specification for major trauma centres[38] (NHS England 2013)). The Royal College of Emergency Medicine (RCEM) produces a number of guidance and standards documents (which can be viewed on the RCEM website at www.rcem.ac.uk) and there is guidance but no published standard for the organisation and management of EDs.

4.7.1.3   For the purpose of this analysis, the functions of the ED might be stated, in order of priority, as follows:

1   to prioritise patients for attention

2   to provide emergency (lifesaving) treatment

3   to diagnose conditions which are time-critical and take immediate action

4   to start or provide definitive treatment[39]

5   to refer on for further investigation, definitive treatment or follow up as required.

4.7.2   Prioritising patients

4.7.2.1   Where demand exceeds capacity to fully assess and treat all patients within an appropriate time frame, a triage system is used to prioritise patients and minimise risk. Many EDs use this in combination with a streaming system at the front door to direct patients to the most appropriate area, which may include a co-located primary care service.

4.7.2.2   Triage is a face-to-face encounter, which the RCEM guidance says should occur within 15 minutes of the patient's arrival or registration and should normally require less than five minutes of contact (Royal College of Emergency Medicine 2017). Triage uses a combination of the patient's presenting

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[38] There are 27 designated major trauma centres in hospitals in England, which provide specialist care and rehabilitation for patients with serious and often multiple injuries, which may cause death or disability.
[39] A selected and complete treatment plan.

complaint and measured physiological parameters (including basic observations such as heart rate and blood pressure) at the time of arrival in the ED.

4.7.2.3 The Manchester Triage System (MTS) (Mackway-Jones K, Marsden J, Windle J, Eds 2014), which was in use at AH1, is a widely used triage method in the UK and Ireland. It has been shown to be effective in detecting critically ill patients when applied correctly by properly trained staff (Cooke and Jinks 1999).

4.7.2.4 The MTS algorithm uses 53 presentations (for example, *'chest pain'* or *'apparently drunk'*) in combination with a set of 195 discriminators (for example *'abrupt onset'*, *'deformity'* or *'cold'*), to assign patients to one of five priority categories, ranging from one (immediate) to five (non-urgent), with associated timeframes in which patients should be seen.

4.7.2.5 The MTS manual does not say what type of clinician should be responsible for patients in each priority group, but it does contain a presentation-priority matrix, which suggests which area of the ED is suitable for each patient, according to presentation and priority level.

4.7.2.6 In Richard's case, the available evidence suggests that there was a delay of 30 minutes before triage took place and that, although he had arrived by ambulance, he walked in and remained initially in the waiting area. He was then triaged using the MTS, with a presentation of *'chest pain'*, which assigned a score of two (very urgent, see within 10 minutes) and was in a *'minors'* cubicle for assessment within 15-20 minutes. The MTS presentation-priority matrix suggests transfer to the resuscitation area for patients with this presentation and priority level.

4.7.2.7 The ED at AH1 was arranged to have a resuscitation area together with high dependency and low dependency cubicles. The investigation was told that the choice of cubicle depended on the triage score, presenting complaint and apparent clinical urgency, but this decision could be influenced by verbal handover from the triage nurse if they had concerns. In this case, Richard appeared relatively well and had little pain. There was apparently no verbal handover by the triage nurse to EDACP.

4.7.2.8 The investigation was told that the type of cubicle in which a patient was placed did not affect which member of the clinical staff then took over his or her care. Staff would select patients in order of arrival from the electronic patient board but patients could be prioritised by a verbal handover, or if there were abnormal investigation results. Patients in high dependency cubicles would routinely have an intravenous (IV) cannula inserted, an IV infusion of fluids might be started and a number of investigations including ECG, chest X-ray and blood tests would be carried out by the cubicle nurse. Although this was the general routine, the investigation was told that there was no documented standard process.

4.7.3 Making a diagnosis

4.7.3.1 The investigation was told that the primary role of the ED is to prioritise patients for emergency treatment or onward referral. However, diagnostic activity must also take place to accomplish the remaining four functions outlined above.

4.7.3.2 Following triage and immediate lifesaving treatment, the immediate role of the ED is one of risk management to detect or rule out time-critical conditions which may be life threatening or lead to irreversible harm. Acute AD is one of a number of relatively rare, hard to diagnose, but time-critical conditions which must be diagnosed or excluded fairly rapidly but are still missed. Others include ruptured ectopic pregnancy, testicular torsion, ovarian torsion, and carotid or vertebral artery dissection.

4.7.3.3 Once urgent treatment is completed, the aim is to refer the patient to the correct speciality (possibly without reaching a diagnosis) and start initial treatment and investigation, or to provide definitive minor treatment and discharge.

4.7.3.4 In practice, risk management and progress towards appropriate referral/discharge occur in parallel. To do this, the ED must function as a system which marshals and deploys its limited resources effectively, including not only expertise and facilities but, crucially, time.

4.8 The emergency department as a decision-making system

4.8.1 The ED is an example of a complex socio-technical system, made up of people (patients, staff, and families), processes and equipment, which includes technologies such as data systems. All parts of the system interact to generate any number of outcomes. It is typical of many other real-world decision-making environments, with high stakes, uncertainty and time and organisational pressures.

4.8.2 Decision-making can be primarily analytical or intuitive (see Appendix 3 for a full explanation), but recent attempts to understand decisions in complex environments describe naturalistic or *'real-world'* strategies where a combination of both types of decision-making is used to achieve a *'good-enough'* result.

4.8.3 This investigation can only consider this subject briefly, but Appendix 3 describes current models of decision making in more detail, examining the reference event from this perspective and how the ED functions as a diagnostic system.

4.8.4 Heuristics and bias

4.8.4.1 Heuristics are the mental short-cuts used by everyone in daily life to make decisions and act in situations recognised from experience. They are generally very effective, particularly in environments such as the ED, which require some way of cutting through the complexity. Heuristics have been described as *'[ignoring] part of the information, with the goal of making decisions more quickly, frugally, and/or accurately'* (Gigerenzer and Gaissmaier 2011). They allow us to achieve what has been described as the *'efficiency-thoroughness trade off'* necessitated by a variety of situational and organisational pressures or suboptimal (less than ideal) conditions (Hollnagel 2017).

4.8.4.2 Much of the time heuristics work well but inevitably they are sometimes mis-applied and then labelled, in hindsight, as biases. This happens particularly when available information is used inappropriately (given or denied weight) in forming a mental model.

4.8.4.3 There are many factors that can lead to such biases, which combine innate human cognitive mechanisms with cultural influences (Kahneman 2012). Practitioner experience is thought to mitigate these biases to some extent (Cohen 1993). Well over 100 biases have been described; three that may be relevant to decisions made in Richard's case are described below.

4.8.4.4 Availability describes the tendency to judge an event by the ease with which similar examples can be retrieved from memory or constructed anew – or, to use a medical aphorism, *'common things are common'.* Knowing that the incident occurred in the gym could increase the likelihood of a connection being made between chest pain and a musculoskeletal origin, or between chest pain and AMI, both diagnoses being much more common than acute AD. However, availability was also helpful in Richard's case, when MSpR's recent memorable encounter with a patient with acute AD led to her quickly considering this as a diagnosis.

4.8.4.5 Anchoring occurs when a decision rests on, and remains too heavily influenced by, information acquired early on. Each assessment – by PM2, EDS, EDACP and FY2 - started with observations to the effect that Richard experienced chest pain while exercising in the gym, now had little pain and appeared well. An initial diagnosis of musculoskeletal pain was made by PM2 and this information was passed to the ED staff, at least in the form of a copy of the written ambulance record. In contrast, perhaps insufficient attention was given to the characteristics of the initial pain.

4.8.4.6 The link made between the gym and musculoskeletal pain is understandable and, perhaps inevitably, persisted throughout the pre-hospital phase and well into Richard's time in the hospital. However, EDACP recognised that the pain was not reproducible and continued to seek an alternative diagnosis although, in the absence of any more compelling explanation, there was a plan to send Richard home.

4.8.4.7 Framing describes the effect whereby the way in which options are presented influences decisions. It was originally used to describe how people are more likely to

avoid risk than seek opportunity, despite equal odds, especially when outcomes are presented in negative terms.

4.8.4.8 Although Richard was taken to the ED by ambulance, he walked in and remained in the walk-in waiting area for some time before and after triage. At least for the first part of his time in the ED, staff were presented with a relatively well looking man. The evidence also suggests that, at each new assessment, there may have been a tendency for staff to frame their assessment according to the appearance of the patient in front of them rather than by the detail of the initial events.

4.8.4.9 Many clinicians probably lack specific heuristics that would work well in acute AD but are likely to be able to draw on a number of other, overlapping, possibilities which might be applied depending on the clinical picture. Because of this, as the evidence suggests, an incorrect diagnosis (or no diagnosis) may be arrived at and possibly pursued for some time.

4.8.5 Managing uncertainty

4.8.5.1 One strategy which people might use to make decisions in uncertain situations was first proposed by Lindblom in 1959. He described it as *'muddling through'* -

using repeated small steps to arrive at an acceptable decision in a complex and not fully-understood environment. In a study of decision-making in the ED, Feufel observed that experienced clinicians used a similar process, combining two strategies – seeking to confirm what is likely (*'common things are common'*), while simultaneously working to exclude the *'worst thing'* (Feufel MA 2009).

4.8.5.2 This idea has been taken up by Flach (Flach JM 2017), who describes the dilemma for the ED physician faced with a patient who *'might'* have an AD. There is no possibility of a perfect solution, but there is a trade-off between pursuing those actions which will exclude the worst thing (acute AD) and treating the common thing but missing a fatal condition.

4.8.5.3 In an echo of this, EDACP described at interview that, although he had many years of experience in nursing (predominantly in orthopaedics and trauma) and the competence to start work on a case, he realised that he did not perhaps have the *"tacit knowledge"* that comes with working in the ED over a long period, and perhaps tended to over-investigate [in order to exclude the worst thing] as a result.

4.8.5.4 The *'payoff matrix'* reproduced in Figure 3 (Flach JM 2017) illustrates both the risks of

FIG 3   THE DECISION-MAKING PAYOFF MATRIX (ADAPTED FROM FLACH JM 2017)
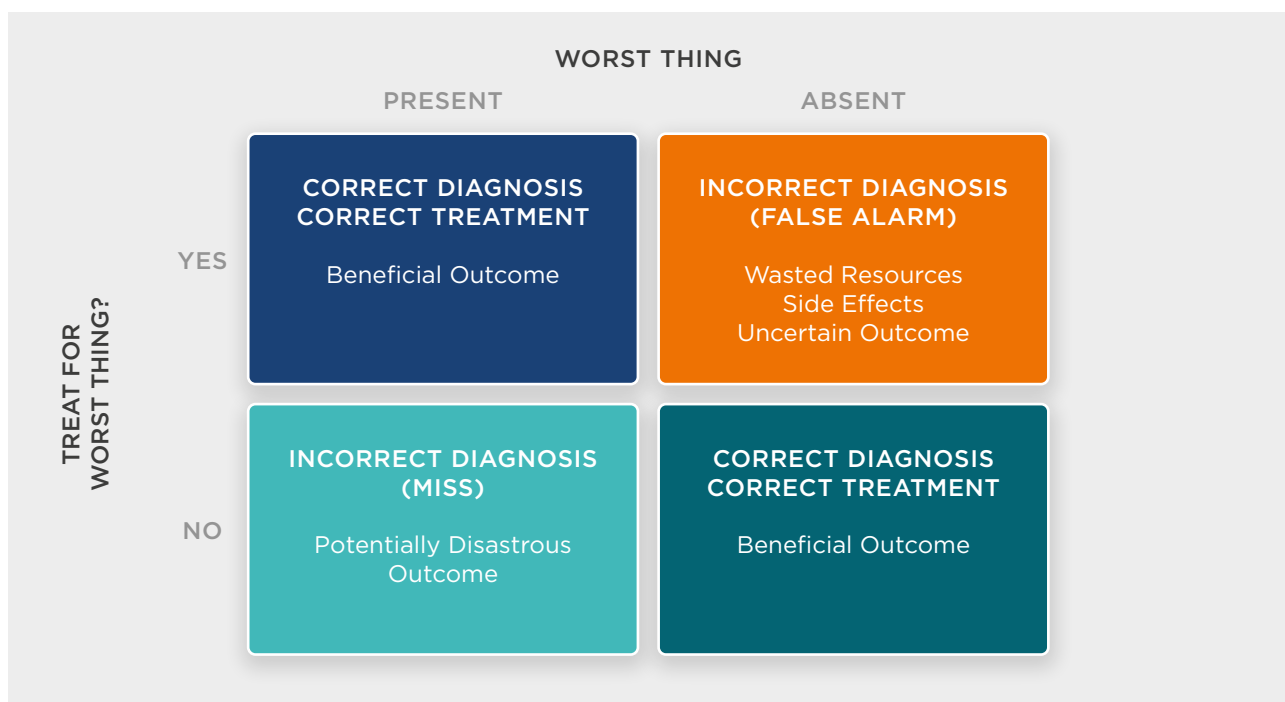
not considering the diagnosis and the adverse consequences of undertaking a CT scan for a patient who has a different diagnosis.

4.8.5.5   The particular problem in patients with acute AD is that repeated parallel small steps may arrive at the correct diagnosis too late (or not at all) without the *'big'* step of a CT scan. Given the severe consequences of misdiagnosis, there should be a wide margin for error.

4.8.5.6   Emergency physicians in the USA are familiar with the concept of risk stratification and the use of risk-benefit analysis for diagnostic testing. One such analysis looked at the use of CTA and D-dimer testing in suspected thoracic AD, finding a very low risk compared to the benefit of performing a CTA (Taylor and Iyer 2013).

4.8.5.7   On the one hand, the very high risks associated with acute AD outweigh the risks of performing a CTA. However, as acute AD is a relatively rare condition, CTA should not be performed unless there are other high risk features present. Richard was, in fact, concerned about the radiation risk of having a CT scan but was persuaded of the need following a discussion with MSpR.

4.8.5.8   These risk-benefit analyses look only at clinical risk and do not consider potential resource implications: availability, time and cost. Ideally, a way should be found to select patients who might have an acute AD for this or other reliable diagnostic imaging tests. In practice, as discussed later, the resource issue – at least for this condition – may not be the obstacle sometimes imagined.

4.8.6   Rule-based decisions

4.8.6.1   Heuristics are more likely to be misapplied in circumstances where there may be no clear diagnostic indicators or a confusing mixture of evidence, such as the presentation of a patient with acute AD. Decision rules can be actual written rules or clinical rules of thumb and could be viewed as explicit heuristics which provide a tool to determine actions. These tools are often both helpful and successful, particularly when applied in the correct context rather than blindly. The fact that they are everywhere in clinical medicine – in the form of protocols, guidance and other less formal knowledge - is an indicator of the complexity of clinical decision making.

4.8.6.2   Successful examples of rule-based decision making in the ED include the triage system. Rather than an experienced clinician making the prioritisation decision, it can be effectively devolved to a less knowledgeable and experienced member of staff who is, however, trained and experienced in using a decision-making tool such as the MTS.

4.8.6.3   While systems such as the MTS might lack the nuanced judgement of an expert, they have the advantage of embodying (and evolving with) the collective experience of a range of practitioners across a number of organisations, offering a level of learning and consistency which an individual might find hard to match. MTS is not entirely rule based - it also requires judgment and experience to apply effectively, using qualitative information such as suspicion or concern.

4.8.6.4   A more simple example might be the blunt ED rule which enforces the RCEM standard that no patient presenting with chest pain should be sent home without being reviewed by a consultant (Royal College of Emergency Medicine 2016b).

4.8.7   Triggering a rule

4.8.7.1   To trigger its application, a rule must be known to the practitioner and there must be one or more conditions that have been correctly recognised as met. The observation that '*diagnosis of this disease requires a high degree of suspicion of an aortic dissection in patients who have some risk factors*' (Evangelista et al. 2016), or words to that effect, is repeated in many of the published articles which address the diagnosis of acute AD.

4.8.7.2   The term *'index of suspicion'* will be familiar to most doctors. More experienced clinicians will have suffered occasions when they regretted not having paid more attention to marginal items of information, as well as others when they have been almost unexpectedly rewarded for attending to *'weak signals'*.

4.8.7.3 Excluding the worst thing first requires the clinician to possess the necessary clinical knowledge and experience to recognise the full range of potential diagnoses. Critically, they also need the opportunity and time to apply their expertise.

4.8.7.4 There are many conditions which can lead to irreversible harm or death. Each evolves at a speed which varies both between patients and condition and each will be accompanied by symptoms and signs which will accumulate to a point where a competent physician will be able to make the correct diagnosis. In the case of acute AD, the symptoms and signs may remain subtle, non-specific or confusing until a relatively late and critical point, such that even experienced clinicians may miss the diagnosis. It is notable that the mean time from arrival in the ED to diagnosis is reported at around four to five hours – longer than in the reference event.

4.8.7.5 The need to attend to *'weak signals'* and the challenge of picking up on these to support *'foresight'* rather than merely reinforcing hindsight must be viewed in the context of a busy department. The ability of the ED system to do this depends critically on the structure, organisation and management of the department. This will include factors such as operational processes, integration and use of technology, the experience and skill mix of staff, their supervision and opportunity to escalate the cases of patients when there is uncertainty or concern.

4.8.8 Emergency department organisation and management affects decision making

4.8.8.1 The typical NHS ED faces significant challenges in organising itself to ensure that decision making is effective and timely. Departments are receiving increasing numbers of patients and, despite a move in recent years from a consultant-led to a consultant-delivered service, they remain reliant on medical and nursing staff with a range of expertise and experience, and those in training grades are rarely supernumerary.

4.8.8.2 There is no obvious or widely applicable solution to the negative influence of resource pressures (including access to expertise) on clinical effectiveness. Resilient design, employing a structured but flexible environment which can be rapidly adapted in response to experience, may provide significant mitigation.

4.8.9 Staffing pressures

4.8.9.1 Research has shown that presenting to an ED during shifts with longer waiting times is associated with a greater short-term risk of re-admission to hospital or death in patients who were deemed well enough to leave the department (Guttmann et al. 2011).

4.8.9.2 However, the shift log for the time period when Richard attended the ED shows that there were no staffing gaps and there were both high and low dependency cubicles available. At 20:00 hours, when he arrived, the department was not under particular pressure, although the waiting time for triage was 25 minutes.

4.8.10 Collective awareness

4.8.10.1 The ED is required to work as a system to discover diagnoses, then formulate and progress initial treatment plans (including investigations) for each patient. A more detailed exploration of this concept is presented at Appendix 3.

4.8.10.2 Effective decision making is driven by good situational understanding[40], which in turn relies on accurate and timely information. Lack of individual or shared situational understanding is a frequent precursor of error.

4.8.10.3 As well as individual situational understanding, there is also a sense in which the department as a whole stores and shares information, has awareness and influences decisions. Information is held by and shared between staff and is also entered into, stored and presented by the electronic or paper patient record system.

4.8.10.4 For many reasons, doctors constantly make decisions based on incomplete information and the use of heuristics or rules. Sharing information contributes additional facts and uses the range of clinical knowledge available in the department to create and develop a collective understanding of each patient.

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[40] Often called situational awareness - an accurate perception of the elements of the environment, which are combined to provide an understanding of their meaning and allow anticipation of events in the short-term future.

4.8.11 Allowing for staff experience and expertise

4.8.11.1 To function efficiently and effectively, the system must also ensure that the decisions that staff are required to take match their level of training and experience.

4.8.11.2 ED staff are faced with a wide range of medical conditions, so it is particularly important that less experienced staff have the opportunity to escalate decision making and are able to recognise when this is required.

4.8.11.3 At the same time, senior staff must be able to monitor activity and detect where their intervention, or at least enquiry, may be required - a key skill which develops with experience. EMC said that it was important for him to monitor the electronic patient board to maintain awareness of activity in the department, particularly after being distracted for a period by the need to undertake or assist with some sort of intervention.

4.8.11.4 Experienced staff must also interact and share information effectively with each other.

FIG 4 SOURCES OF KNOWLEDGE FOR DECISION-MAKING

4.8.12.1 One way that reliance on individual knowledge is addressed in high reliability organisations (HROs) which undertake high risk activities (for example the nuclear industry), is to transfer knowledge and experience (and therefore safety) from the individual to the system (Figure 4).

4.8.12.2 Staff decisions and actions are then based on a synthesis of the collective organisational knowledge and rules with their own knowledge and skills, derived from training and experience.

4.8.12.3 In HROs, establishing and continually improving processes for both normal and *'non-normal'* situations supports staff at each level to apply their own knowledge and experience in a safe and effective manner. Strong mechanisms for rapid local review of events and other learning opportunities ensure that individual experience is incorporated into organisational learning in an ongoing process.

4.8.12.4 For such system learning to be effective, a high degree of organisation and commitment is required. The importance of this for safe healthcare has been recognised by the NHS (Department of Health 2000).

4.8.13 Radiology reporting in the emergency department

4.8.13.1 A chest X-ray was ordered for Richard at 21:30 hours and performed 20 minutes later. At 22:48 hours, an entry in the record by FY2 noted *'CXR nothing obvious abnormal seen'*. However, the radiologist's report made the following day noted that *'the heart is enlarged (CTR = 0.58) and there is widening of the mediastinum.*[41]*'*

4.8.13.2 FY2's interpretation and note regarding the chest X-ray was made an hour after the X-ray was taken and about 40 minutes before MSpR requested the CTA scan. Abnormal chest X-ray features are only present in a proportion of patients with acute AD and are subtle, requiring experience to be reliably identified. The radiologist who subsequently reported the image is likely to have had the benefit of hindsight, as the CTA results were also available by then.

4.8.13.3 It is not possible to speculate as to what FY2 specifically looked for when she examined the X-ray, or whether she would have had the knowledge and experience to search for or recognise the subtle changes which can occur in acute AD, even if the diagnosis had been suspected.

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[41] Cardiothoracic ratio (CTR) is the ratio of the maximum diameter of the heart to the maximum diameter of the chest cavity as seen on chest x ray. This is normally less than 0.5.

4.8.13.4 Although a chest X-ray is not a suitable investigation for detecting AD, Richard's X-ray was requested for entirely different reasons and this is likely to be the case in many patients in whom acute AD is not initially suspected.

4.8.13.5 Chest X-rays are a useful and relatively simple investigation to perform but they are complex to interpret and subtle signs can be highly significant, as in this case. A study by Gatt et al found that ED physicians frequently miss specific abnormalities on chest radiographs, although the clinical consequences are usually not significant. There was a considerable discrepancy between their interpretations and those of trained radiologists, with sensitivity ranging from 20-65%. (Gatt 2003).

4.8.13.6 A large number of chest X-rays are ordered in the ED. RCEM standards on management of radiology results state that *'for most radiological investigations,* [review] *will be done in real time by ED doctors providing an initial interpretation'* and that *'all their radiological investigations* [should be] *reviewed within a time frame of 48 hours of the request by either a radiologist or reporting radiographer'* (Royal College of Emergency Medicine 2016a).

4.8.13.7 The current Royal College of Radiologists (RCR) standards for interpretation and reporting of imaging investigations stress the importance of reporting by a radiologist and the limitations of reporting by non-radiologist doctors (or non-doctors). The standards state that non-radiologist doctors should have *'ready access'* to a radiological opinion. However, no timeframes are specified (Royal College of Radiologists 2018).

4.8.13.8 The findings reported by Gatt et al did not change significantly with the physician's level of training. Even assuming that senior staff would be more accurate in detecting (or at least ruling out) abnormal results, it might not be possible for all radiographs to be examined rapidly by a consultant and radiology departments are under pressure to keep up with an increasing workload. (Care Quality Commission 2018).

4.8.13.9 However, if radiographs are ordered for the purpose of timely and effective decision making in the ED (rather than for medicolegal reasons or future reference), it would seem necessary that the means to accurately interpret them should be available at the time and that this should be embedded as part of the processes of every ED.

4.9 Strategies to detect acute AD in the emergency department

4.9.1 Raising awareness of the presentation of acute AD

4.9.1.1 Limited knowledge and misunderstanding of the presentation of acute AD has been recognised as an issue by the RCEM. There are a number of public campaigns which aim to increase awareness and understanding of the condition, such as Aortic Dissection Awareness (Aortic Dissection Awareness UK & Ireland 2018) in the UK and www.aorticdissection.com in the USA. Review papers are also published from time to time in the medical press (Redfern et al. 2017; Hicks CW, Black II JH 2018; Strauss et al. 2017).

4.9.1.2 In 2016, the RCEM issued a safety alert on acute AD in the form of a poster (Figure 5 (Royal College of Emergency Medicine 2016c)). The key message was to recognise that sudden severe chest pain which is at its worst at onset is characteristic of acute AD. A similar poster has been issued more recently by Aortic Dissection Awareness (Figure 6), together with a podcast (Aortic Dissection Awareness UK & Ireland 2018). Both remind clinicians that, although the condition is rare, it should be considered as a cause of severe chest pain and that the pain is often not the tearing or ripping pain classically described.

4.9.1.3 Although the nature and time course of chest pain appears to be a distinctive feature in a high proportion of cases of acute AD, in Richard's case this information was not recognised as significant and appears to have been lost among other more immediate data. If it had been recognised and led to consideration of acute AD as a diagnosis, this might have resulted a more active search for other corroborative information or an earlier CT scan.

FIG 5   2016 RCEM SAFETY ALERT POSTER

FIG 6   2018 AORTIC DISSECTION AWARENESS POSTER
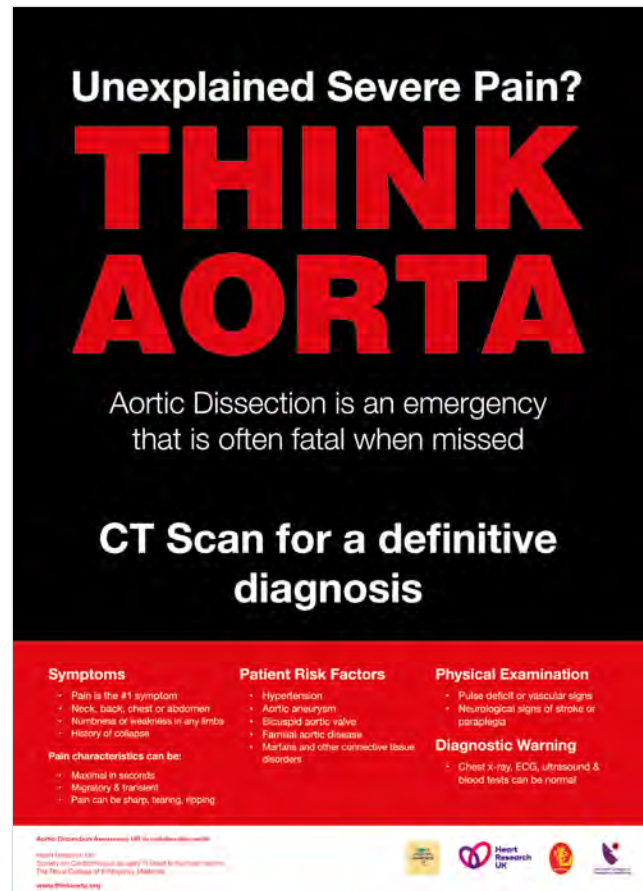
4.9.1.4   To be effective, communications such as those issued by the RCEM and Aortic Dissection Awareness need to be:

1   available
2   read
3   understood
4   memorised and recalled when required.

4.9.1.5   Unfortunately, displaying the poster in a department will only achieve the first of these (and probably only then for a limited audience). In the course of interviews for this investigation, EDSN said that she was not aware of any safety alerts relating to recognition of aneurysm; EDACP was aware of and had *"read briefly"* a poster in the staff room relating to a patient safety alert on recognition of dissecting aortic aneurysm; EMC said that he had been aware of the RCEM *"think dissection"* safety alert, which was sent by email but that he did not feel that the alert was very helpful; MSpR said that she was not aware of any safety alerts relating to this condition.

4.9.1.6   For this type of message to be effective, a more holistic and systematic approach is required to agree and implement changes in practice, which will be incorporated into procedures, documented, publicised, included in training programmes and ideally rehearsed. This would be the strategy in an HRO but is unusual in a healthcare setting where such a systematic approach is less common, resources (particularly time) are scarce, and there are many other competing priorities.

4.9.1.7   A process of this type for acute AD has, however, been implemented with apparent success in the ED at Bristol Royal Infirmary, following several events in which the diagnosis of acute AD had been missed in relatively young men (Redfern 2019).

4.9.1.8   Staff of all grades in that department are trained, authorised and repeatedly reminded and encouraged to request an immediate CTA for patients presenting with the symptoms outlined in the RCEM poster: principally sudden chest pain, at its worst at onset, which may radiate to the back. This was described to the investigation

as *"thunderclap"* chest pain, echoing the description often used to characterise the sudden severe headache classically associated with subarachnoid haemorrhage (a ruptured artery on the surface of the brain).

4.9.2 Considering the possibility of acute AD at triage

4.9.2.1 A further means by which suspicion of the diagnosis of acute AD could be raised early on would be at triage.

4.9.2.2 If the MTS is used for triage (as in Richard's case), the likely presentation selected in acute AD will be chest pain, although as described above there are also a number of other quite varied presenting symptoms which occur less frequently, including neurological symptoms, abdominal pain, and no pain.

4.9.2.3 Once chest pain has been selected as the presentation, the MTS algorithm will then consider the discriminators shown in Table 1 (Mackway-Jones K, Marsden J, Windle J, Eds 2014), with associated descriptions relating to a number of other more common underlying diagnoses[42].

TABLE 1 MTS SPECIFIC DISCRIMINATORS FOR CHEST PAIN

ACUTELY SHORT OF BREATH
VERY LOW SPO2
NEW ABNORMAL PULSE
CARDIAC PAIN
LOW SPO2
PERSISTENT VOMITING
SIGNIFICANT CARDIAC HISTORY
PLEURITIC PAIN

4.9.2.4 The nature of the pain and other symptoms of acute AD makes it likely (as in Richard's case) that the MTS will correctly triage these patients to priority two or even one.

4.9.2.5 If the discriminators were to include an entry for *'aortic pain'* , this could help to bring the possibility to mind at an early stage, particularly as an alternative to cardiac pain, with which this presentation of acute AD is frequently confused. Departments not using MTS would be able to consider adopting an equivalent action.

4.9.2.6 Although there is no definition of *'aortic pain'* and pain associated with acute AD can be misleading, the description given in the RCEM safety alert poster, which includes features such as *'sudden chest pain, maximal at onset'*, appears to have a proven practical value and could be used as the basis for the discriminator.

HSIB MAKES THE FOLLOWING SAFETY RECOMMENDATION

Safety recommendation R/2020/066:
It is recommended that the Manchester Triage International Reference Group considers the addition of *'aortic pain'* to the Manchester Triage System as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

HSIB MAKES THE FOLLOWING SAFETY OBSERVATION

Safety observation O/2020/054:
It would be beneficial if the providers of emergency department triage systems were to consider the addition of *'aortic pain'* as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

4.9.3 A defined strategy for management of non-cardiac chest pain in the emergency department

4.9.3.1 Chest pain is a common reason for ED attendance. Around 5% of patients presenting to EDs have chest pain as their primary complaint, of which around 45% are subsequently diagnosed with a cardiac cause.

4.9.3.2 Other causes of chest pain encompass a broad range of conditions which range from non-urgent to life threatening. The latter include pulmonary embolism, acute AD, aortic rupture, pneumothorax[43], or even oesophageal rupture[44] and the former can be

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[42] Low SpO2 means a low blood oxygen saturation level. Pleuritic pain is chest pain on breathing cased by inflammation of the lining of the lungs.
[43] A collapsed lung.
[44] Rupture of the food pipe.

as diverse as musculoskeletal pain, shingles, pleurisy, pneumonia, or gastroesophageal reflux[45] (Pollack V 2016; McDevitt-Petrovic et al. 2017; Mol et al. 2018).

4.9.3.3   In the absence of a positive cardiac diagnosis, a methodical approach to managing chest pain is important. The risk, although small, of a non-cardiac but life-threatening condition implies that all patients with chest pain must be treated as time-critical until emergent causes are excluded.

4.9.3.4   Although musculoskeletal pain is a real and common cause of chest pain in ED patients, and a cause of significant morbidity, to err on the safe side before accepting this as the cause would require positive demonstration of typical features, as well as the absence of information suggesting an alternative diagnosis.

4.9.3.5   Such typical features would include not only the history but physical signs such as persistence, exacerbation by movement and reproducibility by the medical practitioner. None of these were present in Richard's case but, despite this, there may have been some reluctance to discard this diagnosis with no clear indications of any other cause. The possible role of bias in this has been discussed above.

4.9.3.6   The National Institute for Health and Care Excellence (NICE) published guidance on assessment and diagnosis of chest pain in 2010 (updated in 2016), but this focuses entirely on pain associated with ACS (National Institute for Health and Care Excellence 2016). It recommends considering other causes if ACS is not suspected; however, the only further guidance given is that CT should be used to rule out other diagnoses such as PE or AD but not for the diagnosis of ACS.

4.9.4   Detecting or ruling out AD once it is suspected

4.9.4.1   MSpR said that there were no specific tools or clinical decision-making rules for detecting or ruling out AD, but that the history, bilateral blood pressure measurements, chest X-ray and blood tests were important in making the diagnosis.

4.9.4.2   In 2015, the American College of Emergency Physicians issued a clinical policy, based on a literature review and input from specialist bodies, aimed at addressing key questions in the evaluation and management of patients with acute AD.

4.9.4.3   The policy concluded that there are no clinical decision rules which can be used to reliably exclude a diagnosis of acute AD, and that a negative D-dimer would also not exclude acute AD. The most reliable diagnostic method for acute AD is imaging.

4.9.4.4   Given the number of patients who attend emergency departments with chest pain, the development of an evidence-based strategy to rule out acute AD in patients presenting with chest pain would be useful. If acute AD cannot be ruled out by this means, then imaging would be justified.

4.9.4.5   However, in some ED settings, because of the actual or perceived limited availability of CT, training grade staff in particular may be reluctant to request this for a patient they suspect might have acute AD. A trainee doctor's interpretation of the extent of their authority may not be correct. It may depend on local norms or it might be transferred with the doctor from previous jobs in other hospitals, leading to uncertainty, particularly when there is no clear local guidance.

4.9.4.6   Some departments have attempted to overcome this and other issues with matching radiology resource to ED demand, by agreeing protocols with their radiology colleagues. These specify appropriate investigations according to clinical findings, allowing staff at any level to request agreed imaging without further authorisation.

4.9.5   The AD detection test

4.9.5.1   Rogers et al developed an AD detection (ADD) risk score (Rogers et al. 2011) based on 12 clinical risk markers identified by the American Heart Association and American College of Cardiology guidelines (Hiratzka et al. 2010). The score determines whether patients fall in to one or more high risk categories, based on pre-existing conditions, pain features and examination features, allocating a risk ranging from zero to three (three being highest risk), depending on how many high-risk features are present. The ADD

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[45] Acid regurgitation – the cause of heartburn.

score was applied retrospectively to IRAD data from 1996 to 2009 and was found to be highly sensitive, categorising only 4.3% of patients with AD to a risk score of zero.

4.9.5.2 A recent multicentre prospective study[46] (the ADvISED study (Nazerian et al. 2018)) combined ADD scoring with D-dimer testing. This strategy missed only one case of acute aortic syndrome in 300 patients who had a score of zero and a negative D-dimer result (Corvera 2016). This may lead the way to a reliable means of ruling out acute AD, particularly if more sensitive blood tests are established for the condition.

4.9.5.3 The ADD risk score is a straightforward and rapid score to obtain and could be calculated in a manner similar to that of the Wells score, which was used in the reference event to asses the likelihood of a PE. There is even an online calculator (MDCalc 2019). If this had been applied in the reference event, Richard would have initially scored one, with a recommendation to consider CTA, even without the D-dimer result.

4.9.6 Improving recognition of acute AD in emergency departments

4.9.6.1 It would be beneficial for patients with acute AD, as well as those with other uncommon, harder-to-diagnose and life-threatening conditions, if there were a common strategy for use in EDs to improve their detection and management. In the case of acute AD, such a strategy should form part of a systematic approach to the management of non-cardiac chest pain.

4.9.6.2 The strategy should involve other key disciplines such as radiology, and cardiac and vascular surgery in its development and could draw on the information presented in this report, which forms only a subset of that which is available. It might also be helpful to consider the experience of other industries in which the detection of high impact, low frequency events is an enduring problem, for example the maritime or power industries.

4.9.6.3 The strategy should be applied nationally and would also inform providers of pre-hospital care or advice. To ensure the highest rate of detection without unnecessary use of resources such as CTA, the strategy could be developed over time to increase effectiveness, for example by combining clinical features, such as chest pain, with other indicators such as a raised D-dimer or the ADD score. The strategy should be deployed, evaluated and developed nationally to provide clinical and cost-effectiveness.

4.9.6.4 As an interim measure, it would be beneficial to move as rapidly as is practical towards a model such as that used in Bristol, while working to improve discriminative methods, and starting to collect data on acute AD from EDs.

HSIB MAKES THE FOLLOWING SAFETY RECOMMENDATION

Safety recommendation R/2020/067:
It is recommended that the Royal College of Emergency Medicine, together with the Royal College of Radiologists, develops, deploys and evaluates a national evidence-based process to detect and manage patients with acute aortic dissection presenting to emergency departments. The process should form part of a wider strategy for managing non-cardiac chest pain in the emergency department.

4.10 More general strategies for reducing diagnostic error

4.10.1 Diagnostic decision making is an essential skill, but is not always addressed in undergraduate curricula and is often assumed to be automatically acquired during training (Croskerry and Nimmo 2011). It is an unreliable activity and diagnostic errors are frequent. There have been estimates that the error rate is between 10-15% across medical domains (Schiff et al. 2009).

4.10.2 Interventions to avoid cognitive bias when making fast intuitive decisions are problematic because of the difficulty of changing people's subconscious thought processes and have not generally been successful (Graber et al. 2012).

4.10.3 One possibility is to improve metacognition - the ability to reflect on one's own thought processes - which is described in more detail in Appendix 3. Questioning one's own assumptions and conclusions, however obvious, appears to be a helpful, although effortful, device.

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[46] A prospective study is planned in advance, and waits for patients to present with the condition over a period of time, rather than using the 'retrospective' data of patients who have already been seen.

4.10.4 It has been suggested that reflective practice promotes metacognition and incorporates four distinct elements: seeking out alternative explanations, exploring consequences of alternative diagnoses, being open to tests that would differentiate the various possibilities, and accepting uncertainty (Moulton 2007).

4.10.5 Reviewing alternative diagnoses is one approach to improving decision-making: asking *'could this be something else?'* and using appropriate tests to exclude the alternatives, rather than ordering tests that simply confirm original suspicions (Taleb 2007).

4.10.6 In his book, How Doctors Think, Jerome Groopman describes at least three separate cases of missed AD (Groopman 2011). He discusses in particular the role of patients and families and how they can help to improve doctor's thinking and decision making by asking specific questions, which are directed at avoiding the three most common errors: anchoring (premature closure/satisficing), availability and attribution[47]:

A what else could it be?

B could there be more than one thing going on to explain my problem?

C is there anything in the history, examination or test results which seems to be at odds with the working diagnosis?

4.11 Pre-hospital recognition of acute AD

4.11.1 Richard presented to three different parts of the healthcare system: NHS 111, the ambulance service, and the ED.

4.11.2 This investigation has focused on the emergency department, but effective management of acute AD requires coordinated, multidisciplinary care across the entire health network to achieve optimal outcomes. This starts with improving the ability of providers on the front line to suspect or recognise the diagnosis.

4.11.3 This type of co-ordinated approach can shorten critical time delays in delivering appropriate treatment for patients in

a large geographic region. There are a number of examples where this has been implemented, such as in Minneapolis (Harris et al. 2010). Di Wang and colleagues go even further, noting that '*for patients with acute myocardial infarction, the missed diagnosis of aortic dissection could be catastrophic'* and recommending that portable echocardiography should be routinely available in the ambulance (Di Wang et al. 2018).

4.11.4 RCEM guidance acknowledges that, '*in an ideal system, the ED initial assessment would be linked to pre-hospital assessment and triage, although the risk of diagnostic anchoring, and confirmation bias, should be acknowledged, and assessment should be repeated to detect any deterioration. Access to patient records and notes is helpful'* (Royal College of Emergency Medicine 2017).

4.11.5 To a large extent, the diagnostic process started again at each stage of Richard's journey, both before and during his time in the ED. Both pre-hospital services carried out triage and diagnostic activities independently, although information would have been passed between them on handover, as well as between the three clinicians who led the management of Richard's case within the hospital.

4.11.6 Information handed over between services could transfer bias or crystalise assumptions as fact but might also have some advantages, particularly during an escalation process. In practice, some information is nearly always passed on but, in principle, each new practitioner sees the patient with fresh eyes and without priming. This could have provided the opportunity for a fresh consideration of the crucial information regarding the initial onset of pain.

4.11.7 The investigation was told that *"minimal"* information is normally passed from NHS 111 to the ambulance service, although referrals to primary care are accompanied by a documentary record of the call. It is not known whether or how the call by NHS 111 to the ambulance service might have affected the preconceptions of the ambulance crew, or how the handover from the ambulance

[47] Anchoring and availability have been described above. Satisficing refers to a decision-making strategy which aims to achieve an adequate (rather than optimal) result. It may cause situations where a decision has been reached without sufficient information being sought or considered, described as premature closure.

crew to the ED may have conditioned the views of the hospital staff.

4.11.8 NHS England has developed a national service specification for commissioners and service providers, covering the provision of a functionally integrated 24/7 urgent care access, clinical advice and treatment service (incorporating NHS 111 and out-of-hours services) (NHS England 2017).

4.11.9 The Integrated Urgent Care Key Performance Indicators and Quality Standards 2018 Standard 11: Identification of Life-Threatening Conditions states that *'providers must have a robust system for identifying all immediate life threatening conditions'* (Figure 7 (NHS England 2018)).

4.11.10 The findings of this investigation may be relevant for the ambulance service, telephone advice networks and primary care, and assist providers and commissioners in meeting this standard.

4.11.11 Although the diagnosis of acute AD was not recognised until some hours into Richard's hospital admission, the pre-hospital response

actions taken for him were correct. The ambulance service was contacted by NHS 111 and Richard was essentially transported to AH1 because of a concern that his chest pain could have been caused by an AMI.

4.11.12 Richard was also, however, advised to take aspirin by the NHS 111 call handler, which may have adversely affected his condition.

4.11.13 The investigation was unable to obtain any records from NHS 111 to understand how the NHS Pathways algorithm[48] used by the call handler functioned in this case and whether it might have had the capability of identifying a patient with acute AD and distinguishing the presentation of this condition from that of AMI.

4.11.14 Richard was asked by the NHS 111 call handler about the severity of the pain and whether it was like a sudden agonising, ripping or tearing pain. Although he agreed that the pain had initially been severe, he did not confirm this description of its nature.

4.11.15 The investigation was informed that, as a result of ongoing review of the NHS

FIG 7 INTEGRATED URGENT CARE CALL FLOW (ADAPTED FROM NHS ENGLAND 2018)
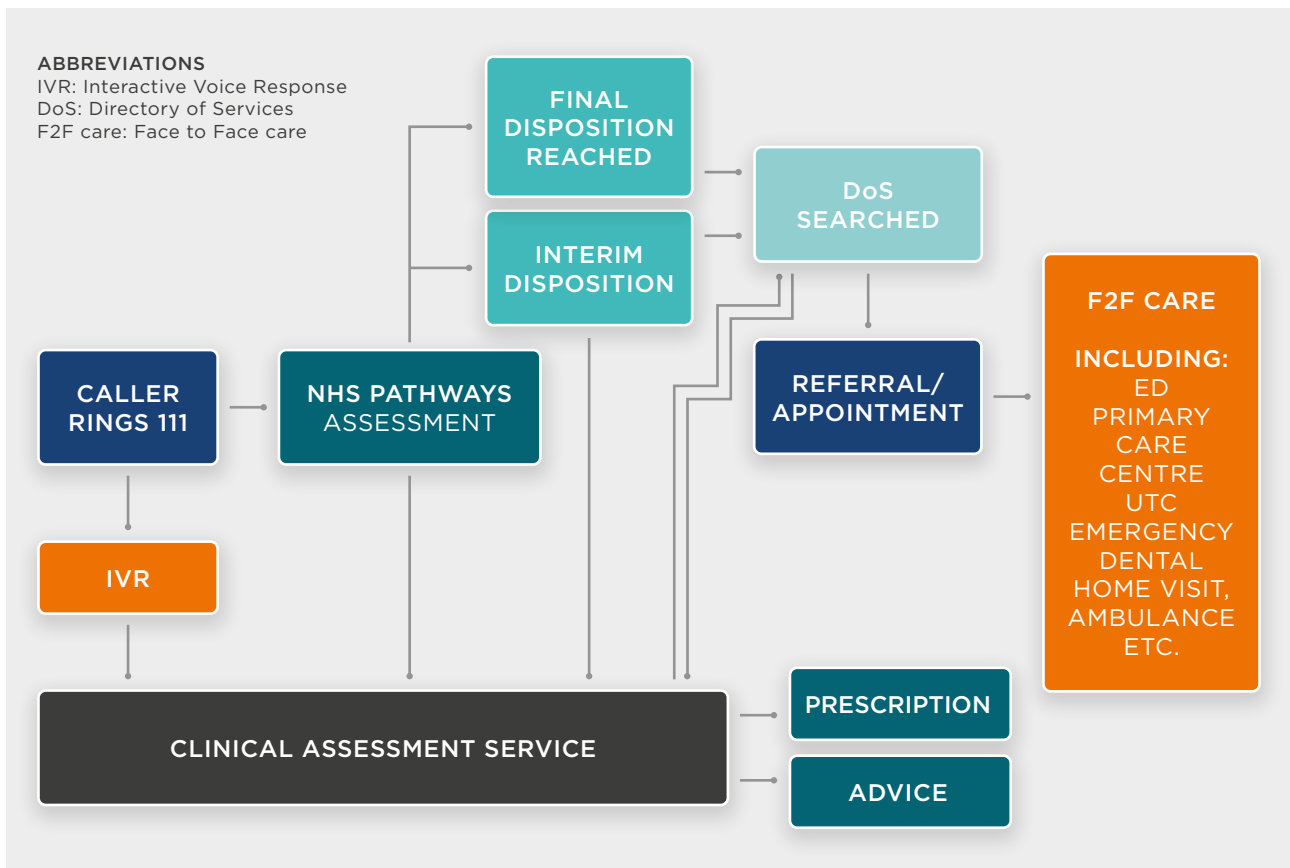
[48] NHS Pathways is a clinical tool used for assessing, assigning a level of urgency to and directing calls made to NHS 111. The tool uses an algorithm to provide call handlers with questions to ask, actions to take and advice to give.

Pathways content, detailed clinical review in relation to the presentation of aortic emergencies has resulted in this question being replaced by two new questions (NHS Digital 2019):

- *'Did the pain come on suddenly over a few seconds?'*

- *'Is it a ripping or tearing pain?'*

4.11.16   The call handler guidance notes include advice that this means *'agonising pain'* coming on *'suddenly over a few seconds, striking the individual like a clap of thunder'*.

HSIB NOTES THE FOLLOWING SAFETY ACTION

Safety action A/2020/019:
In release 18, NHS Digital has amended the content of the NHS Pathways algorithm used for telephone triage of patients, to help improve recognition of chest pain likely to be associated with acute aortic dissection.

4.12   Immediate actions once acute AD is diagnosed

4.12.1   Referral and transfer

4.12.1.1   The 2014 ESC guidelines state that all patients with type A AD should be sent for surgery. In Richard's case, once the diagnosis was confirmed he was immediately accepted by the RCC and an emergency ambulance requested to transport him there. The ambulance arrived just over 20 minutes after it was requested and departed with Richard and his partner 10 minutes later.

4.12.2   Stabilisation of blood pressure and heart rate

4.12.2.1   Both the 2014 ESC and the 2010 USA guidelines recommend measures to reduce stress on the aortic wall to prevent extension or rupture, by controlling pain, heart rate, and blood pressure prior to surgery or during transfer. Initial targets of systolic blood pressure of 100-120mmHg and a heart rate of less than 60bpm are quoted. Although there is no evidence on which these figures are based, the investigation was advised that the physiological rationale behind the recommendations is sound.

4.12.2.2   The ITU consultant (ITUCons) said that guidance on transfers such as who to transfer, when to transfer, and escort requirements, was set out in the AH1 Anaesthetic Clinical Services Handbook. Trainee doctors are given a handbook explaining transfer and a transfer training module is included during attachments in intensive care. ITUCons also referred to national guidance on transfers published by the Association of Anaesthetists, which is available online (Association of Anaesthetists 2009).

4.12.2.3   Although it does not refer specifically to acute AD, the Association of Anaesthetists guidance includes advice on stabilisation before transfer, addressing the balance of urgency for definitive treatment against the need for stabilisation before transfer. It states *'For example, transfer of a patient with a leaking aortic aneurysm to a vascular centre may be time-critical. Even in these situations the transfer should not begin until essential management and monitoring has been undertaken.'*

4.12.2.4   The AH1 Transfer Policy in force at the time of the reference event stated that *'most problems in transit occur because the patient has not been adequately stabilised and prepared prior to moving. It is essential to optimize the patient's condition before transferring'.*

4.12.2.5   However, it goes on to say that *'in rare cases, it may be appropriate for the patient not to be stabilised before transfer e.g. ruptured/ dissecting aortic aneurysm. Consultant advice should be urgently sought as well as the advice of the receiving hospital'.*

4.12.2.6   In this respect, the actions of the staff at AH1 complied with the local guidance in force at the time, although it might be prudent to review this advice for patients with acute AD in the light of the specialist recommendations, this event and other experience. It would also be helpful if specialist receiving units were able to give consistent and up-to-date advice to sending hospitals which would reinforce use of best practice.

4.12.2.7   In Richard's case, a judgement call was clearly required at the time. However, given his persistent vomiting and the further psychological and physiological stress

caused by receiving the diagnosis and the ambulance transfer, the relatively small additional delay that would have been required to establish appropriate control measures might have been time well spent.

4.12.2.8 This subject is considered in more detail in the HSIB report covering the first part of this investigation (Healthcare Safety Investigation Branch, Transfer of critically ill adults 2019b).

HSIB MAKES THE FOLLOWING SAFETY OBSERVATION

Safety observation O/2020/055:
Current recommendations for all patients with acute aortic dissection specify immediate measures to control blood pressure and heart rate. Non-specialist hospitals which may dispatch these patients to specialist centres might wish to review their guidance and instructions to staff in this respect. Specialist centres accepting patients with this and other life-threatening conditions could consider developing clear instructions for dispatching hospitals regarding preparation and transfer of patients, in line with best practice.

4.13 Effect of this event on the staff and local learning

4.13.1 The investigation attempted to gather information about feedback and learning at AH1 resulting from this event. All staff interviewed by the investigation had been very upset to hear of the outcome.

4.13.2 The trust conducted a comprehensive investigation which found that this was a rare and difficult-to-diagnose condition for which the only remedy was transfer to the RCC. It found that local guidance on management of chest pain to immediately exclude an AMI was not adhered to and that bilateral blood pressure readings should have been performed once an AMI was excluded. It recommended that, in the absence of a medical escort in the ambulance to the RCC, a nurse should have accompanied and supported Richard's partner.

4.13.3 The HSIB investigation was told that regular morbidity and mortality reviews carried out in the ED only considered events which occurred in the ED and that this case was therefore not discussed. However, bilateral blood pressure readings are now routinely taken in patients under the age of 60 years.

4.13.4 When he returned to work the following day, EDACP reviewed Richard's medical record for his *"own learning and to see what had happened"* and was shocked and saddened to find out what had happened.

4.13.5 MSpR carried out an informal debrief with nursing staff after Richard's departure.

4.13.6 Some staff told the investigation that they had been very affected by this event for some weeks afterwards, but had not had any opportunity to discuss the event with anyone.

5 SUMMARY OF FINDINGS, SAFETY RECOMMENDATIONS, SAFETY OBSERVATIONS AND SAFETY ACTION

5.1 Findings from the reference event

5.1.1 The medical professionals who treated Richard prior to his hospital admission and in the Emergency Department (ED) did not recognise that the sudden onset of severe chest pain might be a symptom typical of acute aortic dissection (AD).

5.1.2 There appeared to be a lack of awareness among medical staff of the most common symptoms and signs of acute AD and the limitations of measuring the blood pressure in both arms as a diagnostic test for this condition. There also appeared to be confusion for some staff between the presentation of an acute thoracic AD and an abdominal aortic aneurysm.

5.1.3 The NHS 111 triage resulted in an appropriate response, but the patient was advised to take aspirin, which could have had serious adverse consequences in this condition.

5.1.4 Richard was taken to hospital to rule out an acute myocardial infarction as the cause of chest pain. However, he waited over 30 minutes for triage and, although his case was assigned to priority two (of five, with one being the most urgent), Richard was then placed in a low-dependency cubicle.

5.1.5 Although Richard's pain could not be reproduced in a way which would have positively supported the presence of a musculoskeletal injury, there was some reluctance to relinquish this as a possible diagnosis while the possibility of a more serious heart or lung problem was being explored.

5.1.6 During his time in the ED, Richard was not seen by a consultant but by an advanced care practitioner and a foundation year two (FY2) doctor. The FY2 doctor discussed the case with, and received advice from, a consultant.

5.1.7 There was a delay in escalation of the case of an apparently well patient with a history of chest pain but without a clear diagnosis.

5.1.8 A chest X-ray taken in the ED was incorrectly interpreted as normal. A chest X-ray is not a suitable investigation for detecting acute AD.

5.1.9 The current Royal College of Emergency Medicine standards for management of radiology results were complied with.

5.1.10 The delay in this case - of around four hours in the hospital - before reaching the diagnosis of acute AD is not unusual.

5.1.11 Once the diagnosis was made, there was a further wait of over an hour for a formal report of the Computed tomography aortogram (CTA) scan before the patient could be referred to the specialist centre.

5.1.12 Once referred to the specialist centre, the patient was immediately accepted and the ambulance departed within an hour.

5.1.13 Immediate measures to control blood pressure and heart rate in patients with diagnosed acute AD are recommended. These measures were considered prior to Richard's transfer but were ruled out to save the time needed to institute them and to avoid the requirement for a medical escort.

5.2 Findings from the wider investigation

5.2.1 The investigation was unable to discover national data which would allow an accurate understanding of the incidence and patient outcomes for acute AD in England.

5.2.2 Analysis of hospital activity, other national data and published literature suggest acute AD may occur in around 4.5 per 100,000 of the population per year (approximately 2,500 cases per year in England). Around 20% of patients with acute AD die before reaching any hospital and 50% die before reaching a specialist centre.

5.2.3 Acute AD is a rare cause of chest pain, particularly in comparison to acute myocardial infarction. Staff in non-specialist hospitals may be unfamiliar with the condition and its presentation, as it is seen relatively infrequently and symptoms can vary or be confusing.

5.2.4 A delay in diagnosis of acute AD occurs in around 16-40% of cases and is more likely if the patient walks in to the hospital or a cardiac cause for chest pain is initially suspected.

5.2.5 Accuracy of interpretation of chest X-rays is improved when reporting is carried out by expert radiologists. Early availability of expert chest X-ray interpretation may improve the ability to make accurate time-critical treatment decisions in the ED.

5.2.6 A definitive diagnosis of acute AD can only be made by using specific imaging techniques (usually a CTA).

5.2.7 Acute AD is one of a number of low-frequency, high-risk conditions which are recognised as more likely to be missed in the ED.

5.2.8 Strategies are available which, if employed, would reduce delay in recognition of acute AD both in the ED and in pre-hospital care settings.

HSIB MAKES THE FOLLOWING SAFETY RECOMMENDATIONS

Safety recommendation R/2020/066:
It is recommended that the Manchester Triage International Reference Group considers the addition of *'aortic pain'* to the Manchester Triage System as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

Safety recommendation R/2020/067:
It is recommended that the Royal College of Emergency Medicine, together with the Royal College of Radiologists, develops, deploys and evaluates a national evidence-based process to detect and manage patients with acute aortic dissection presenting to emergency departments. The process should form part of a wider strategy for managing non-cardiac chest pain in the emergency department.

HSIB MAKES THE FOLLOWING SAFETY OBSERVATIONS

Safety observation O/2020/053:
There is a lack of detailed and accurate data regarding the incidence and patient outcomes for acute aortic dissection in England, particularly for those patients who do not reach a specialist treatment centre alive. Such data would assist in understanding the true scale of the problem and where any interventions might be directed.

Safety observation O/2020/054:
It would be beneficial if the providers of emergency department triage systems were to consider the addition of *'aortic pain'* as a discriminator for chest pain, to raise awareness of acute aortic dissection as a potential cause.

Safety observation O/2020/055:
Current recommendations for all patients with acute aortic dissection specify immediate measures to control blood pressure and heart rate. Non-specialist hospitals which may dispatch these patients to specialist centres might wish to review their guidance and instructions to staff in this respect. Specialist centres accepting patients with this and other life-threatening conditions could consider developing clear instructions for dispatching hospitals regarding preparation and transfer of patients, in line with best practice.

HSIB NOTES THE FOLLOWING SAFETY ACTION

Safety action A/2020/019:
In release 18, NHS Digital has amended the content of the NHS Pathways algorithm used for telephone triage of patients, to help improve recognition of chest pain likely to be associated with acute aortic dissection.

6   APPENDICES

Appendix 1: Summary of key events and times

Time (24 hour clock)	Elapsed time	Event
18:00	0:00	Onset of pain
18:40	0:40	Call to the NHS 111 service
19:04	1:04	Ambulance arrives at home
19:17	1:17	Ambulance service ECG
19:37	1:37	Ambulance departs
20:04	2:04	Ambulance arrives AH1
20:12	2:12	Richard arrives in the ED (sits in waiting area)
20:46	2:46	Triage started. Observations: pulse 128, blood pressure (BP) 108/47, respiratory rate (RR) 17
20:49	2:49	Triage signed (Richard returned to waiting area after triage)
21:00	3:00	Richard placed in cubicle (estimated time)
21:01	3:01	Blood collected (received at 21:10 hours)
21:21	3:21	EDACP clerking note: 'Looks well. Differential diagnosis…Musceloskeletal chest pain Lower respiratory tract infection…Cardiac chest pain'
21:30	3:30	Chest X-ray requested (by EDACP)
21:41	3:41	First ECG
21:50	3:50	Chest X-ray performed
22:48	4:48	FY2 note on handover from EDACP: 'to chase bloods and CXR [chest X-ray] ?home'; 'CXR nothing obvious abnormal seen'; 'Bloods Trop T 30 D dimer >3000'. 'O/E Athletic looking gentleman. walking round ED. Sats 100% on air'…'Discussed with [EMC] he advises to refer to medics ? cause of chest pain ?? suspicious malignancy. Med SpR bleeped'
22:52	4:52	Richard given ondansetron 4mg IV
22:58	4:58	Note by FY2: 'Pt vomited in the toilet. Generally doesn't feel very well. got back pain. and feels like indigestion. Discussed with Medical SpR who has kindly accepted'
22:59	4:59	AMU clerking; completed at 23:45 hours
23:02	5:02	Blood results reported including troponin T 30 ng/l and D-dimers >3,000ng/ml
23:03	4:58	Second ECG
23:27	5:27	CTA requested (by MSpR)
23:28	5:28	ED summary generated by the EPR system
23:30	5:30	Estimated arrival in AMU – social history taken by AMUN
23:31	5:31	FY2 note: 'BP done in both arms. In one arm systolic was 100, in other arm systolic was 123'
23:33	5:33	Observations including pulse 55, BP 141/8, RR 18
23:51	5:51	MSpR note: 'Now has diarrhoea and vomiting, no blood in either…Has internal bilateral flank pain now, not tender to palpate…Looks grey, clammy, unwell…I note BP was unequal - 20mmHg difference…Concerning constellation of history and blood tests ?dissection ?thrombus - ?ischaemic bowel'
00:01	6:01	CTA chest/abdomen/pelvis
00:08	6:08	IV infusion (Hartmann's solution) started
01:06	7:06	CTA report received
01:26	7:26	Request for ambulance
01:27	7:27	Richard given paracetamol 1g IV
01:41	7:41	Richard given ondansetron 8mg IV; cyclizine 50mg IV
01:48	7:48	Ambulance arrives at AH1
01:57	7:57	Ambulance departs AH1 with Richard and his partner
02:09	8:09	Richard suffers cardiorespiratory arrest
03:15	9:15	Richard pronounced dead
09:54	15:54	Chest X-ray report: 'The heart is enlarged (CTR = 0.58) and there is widening of the mediastinum'

Appendix 2: List of blood tests

The table below provides a brief description of those blood tests which are mentioned but not explained elsewhere in the report.

Test name and abbreviation	Explanation
Full blood count (FBC)	The number of each type of cell in the blood, including red blood cells, which carry oxygen, white blood cells, which fight infection and platelets, which help blood to clot.
Urea	A breakdown product of proteins, mostly excreted by the kidneys and used as an indicator of kidney function.
Creatinine	A waste product produced by muscles and excreted by the kidneys. The level in the blood is used as an indicator of kidney function.
Electrolytes	Minerals, including sodium, potassium and chloride, the concentrations of which are frequently used to check for metabolic disturbances (problems with the body's essential chemical processes).
Glucose	A sugar found in the blood which is essential for many processes. Levels are particularly disturbed in patients with diabetes.
Prothrombin time (PT)	A test of blood clotting function.
Activated prothrombin time (APTT)	A further test of clotting function used in combination with PT.
C reactive protein (CRP)	A protein released in response to tissue injury indicating an infective or inflammatory process.
Liver function tests (LFTs)	The liver takes up drugs and toxic substances from the blood and renders them harmless. These tests measure the levels of a number of enzymes and other substances released when there is liver malfunction. However, raised levels of some of these can occur other conditions, without any liver abnormality.
Cholesterol	An important building block of tissues, hormones and enzymes; raised levels of this can increase the risk of cardiovascular disease.
Bone profile	Measures a number of proteins, minerals and enzymes involved in bone growth, breakdown and replacement. May be abnormal when there is bone disease, including secondary deposits from cancers.

Appendix 3: Decision making in the emergency department – a human factors commentary

1 Decision making in the emergency department

1.1   Decision making in the emergency department (ED) shares features typical of many other real-world decision environments, including high stakes, uncertainty, conflicting goals, time and organisational pressures. Arguably however, in a significant number of cases, the stakes are never higher.

1.2   As in many naturalistic decision-making contexts, there may be no logically or statistically correct optimal (best) decision, or conditions may preclude the application of structured decision processes due to limited time, information or resource.

1.3   Before suggesting different ways of working, it would be helpful to understand how decision makers tend to make effective decisions more often than not, and then to look at the decision contexts to see whether there may be opportunities to provide support to both the analytical and also the intuitive decision making processes, to allow better decision making in the future.

2 Current views on decision making

2.1   One of the critical debates in the scientific and human factors applied research communities relates to two different modes of decision making – an analytical mode and an intuitive mode[49] -see Kahneman's book Thinking, Fast and Slow for a recent description of this distinction (Kahneman 2012).

2.2   The analytical mode is characterised by deliberate, conscious, systematic treatment of variables which influence a decision. The intuitive mode is characterised by rapid, subconscious, often experience-based assessments and decisions. In the past, analytical approaches to decision making were often prescribed as the only right way to make decisions based on objective, rigorous analysis of all the evidence; the intuitive approach described satisfactory rather than optimal decision making, based on experience and often limited by access to information and time.

2.3   More recently, there have been efforts to understand how skilled decision makers make *'good enough'* decisions in contexts characterised by uncertainty, time pressure and complexity (so called *'naturalistic decision making'*). In Klein's recognition-primed decision model, analytical processes focus on *'understanding the problem space'* through situation assessment and sensemaking processes (Klein G, Phillips JK, Rall EL, Peluso DA 2007) and on *'evaluating a course of action/option'* in a serial manner, often through mental simulation (Klein GJ 1995).

2.4   Real world decision making is frequently some combination of both analysis and application of knowledge and experience or intuition, depending on the decision problem, its context and the experience of the decision maker (Kahneman and Klein 2009).

2.5   The standards being contrasted are the optimal, or best, decision versus a satisficing, or good enough, decision. This can sometimes include the better of two or more potential negative outcomes, but usually means sufficient to stabilise or even resolve a situation without putting a decision maker in a worse position for future decisions. It has been described as '*muddling through*' and is a feature of *'messy'* contexts, where decision makers use their knowledge and experience to navigate uncertainty: missing, ambiguous, conflicting or just complex information, time pressure, conflicting goals, organisational pressures, and so forth (Flach JM 2017).

2.6   The use of adaptive mental short-cuts known as heuristics was first discussed in the early 1970s, by Kahneman and Tversky. They highlighted a number of systematic errors in decision making which heuristics may lead to if inappropriately applied and which they referred to as biases (Tversky and Kahneman 1974). Since then, over 175 biases have been identified (as evidenced by the commonly-referenced Cognitive Bias Codex, a diagrammatic representation of over 180 biases developed by Manoogian and Benson (Benson 2016)).

2.7   However, there is disagreement with respect to the applicability of the bias concept to many real-world decision-making contexts (Klein GA 1989; Cohen MS 1993). Experience,

49 Also described as two ends of a continuum from analytical to intuitive or experience-based.

knowledge and sometimes expertise are often essential to complete a task; without heuristics decision makers in many real-world decision contexts would be paralysed by inability to cut through the mess and complexity.

2.8   As biases can only be labelled as such after the event, a list of biases will not help to predict how a decision maker may err or allow specific interventions to be put in place to avoid them, without disabling the adaptive and, in many cases necessary, heuristics themselves.

2.9   Metacognition - awareness and understanding of one's own thought processes - might allow us to appreciate what short-cuts we might be taking, and whether those short-cuts are appropriate given the current decision context. However, merely being aware of our biases (but not necessarily the heuristics and other factors which are conducive to systematic error types) does not always help performance.

2.10   Instead, one of the major factors which reduces the likelihood of these types of errors in thinking is the degree of understanding of the underlying dynamics and behaviours of the system. This allows generation of appropriate mental models of the problem, based on learning and experience - for example, base rate probabilities, and therefore likelihoods, of underlying medical conditions.

2.11   Efforts are often made to improve those mental models through education, learning and development activities; for example, including activity debriefs and structured reflections which focus not only on what went right and wrong, but also on why. See Hutton, Ward and Capewell (Hutton RJB, Ward P, Capewell D. 2017) and Phillips, Klein and Sieck (Phillips JK, Klein G, Sieck WR 2004) for a description of decision-centred approaches to after action reviews, which support the unpacking of the problem or decision space as well as the actions that supported the decision making process.

3   The emergency department as a system

3.1   The ED is an example of a complex socio-technical system, made up of people (patients, staff, family and other agencies) as well as technologies and data systems. The

parts of the system interact to generate any number of outcomes, which may or may not be reliable or predictable.

3.2   The system is bounded by legal requirements, rules, regulations, policies and procedures, training and education, measurement and testing systems, feedback loops, information systems, ways of working for individuals and teams, and individuals' knowledge and experience.

3.3   As described in the body of the report, the investigation was advised that the purpose of the ED is not necessarily to provide a definitive diagnosis, but to progress the patient's case to the point at which they can be moved to the appropriate clinical specialty or sent home, for potential follow up if required.

3.4   A key challenge is the prioritisation of resources to patients based on the degree that the medical problem is life threatening and time-critical. Processes are already embedded in the ED which act as clinical short-cuts to support this prioritisation and to avoid having to treat every patient (analytically) as a blank slate requiring a comprehensive and time-consuming testing and diagnostic protocol.

3.5   Both streaming and triage are heuristic approaches to meet the goal described above. Triage is applied in an environment where there is a strong evidence base for matching symptoms and basic observations with broad clinical problem areas, supporting rapid initial assessment and prioritisation of clinician's time and diagnostic resources.

3.6   Following triage, the physician's job, assuming a non-life threatening situation requiring immediate intervention, is to narrow down the patient's medical problem sufficiently to ensure that they get passed on to the right specialty for treatment, or sent home with a plan of action for subsequent care. This is achieved by means of the traditional history, examination, observations and special investigations. However, the decision about what to do with a patient without a definitive diagnosis requires further work.

4 Decision making in the reference event

4.1 A key task for any incident investigation is to understand how each individual's decisions and actions, such as working or definitive diagnoses and interventions or treatments, made sense to him or her at the time and with the information at hand. This means understanding what the key judgments, assessments and decisions were, what made those decisions easy or difficult, and how they were made.

4.2 By understanding this, it may be possible to ascertain whether there are areas for improvement with respect to individual performance, team performance, support technologies or organisational ways of working, including procedures and policies.

4.3 One approach would be to adapt methods used in research and human factors practice referred to as cognitive task analysis (Crandall et al. 2006) or cognitive work analysis (Jenkins 2009).

4.4 These methods include the use of observation of normal operations, and knowledge elicitation and knowledge representations[50] for the incident itself. Inferences can be made based on the current cognitive models and theory described in the introduction above - for example, referring to models of analytical decision making, experiential (intuitive, rapid) decision making, the application of heuristics and associated biases. Models of collaborative and team analysis, sensemaking, problem solving, planning, and team decision making can also be applied.

4.5 This investigation has used various sources of evidence to understand clinical decision making in the reference event, including electronic and physical patient records (which may or may not include accurate timing or complete data), together with interviews with the people involved. The detailed narrative of the reference event has been assembled from this information and is set out in section 2 of the report.

4.6 A limited amount of observation of normal operations has also been undertaken, although far less than would normally be required for a comprehensive evaluation

of decision making in this context. Nevertheless, the experience gained has been used to inform the methodology of subsequent HSIB investigations.

4.7 This investigation has relied heavily on interviews, which can have limitations in terms of accuracy and reliability. Unlike an aviation investigation, there is no black box flight data recorder or cockpit voice recorder from which to reconstruct the events with an accurate and comprehensive timeline, although the electronic patient record does at least indicate when entries were made.

5 Key decision-making themes

From the above, the following themes were identified as relevant to exploring and understanding the clinical decision making involved in such hard-to diagnose cases in the ED:

- diagnostic approaches – mechanistic, qualitative and holistic

- negative cues or absence of symptoms

- diagnostic tempo/momentum and time constraints

- the role of suspicion and hard-to-quantify or qualitative information as drivers

- distributed cognition in the ED

- team decision making, coordination and responsibility

- expertise and experience in the ED

- trade-offs and competing demands.

These are explained further below.

5.1 Mechanistic, qualitative and holistic data

5.1.1 Decision making in the ED uses a contrasting combination of a quite mechanistic collection and use of quantitative data (observations and test results) together with more qualitative subjective assessments and descriptive narratives of the patient's history and current experience of the problem.

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[50] When studying experts in a particular field, knowledge elicitation is the process of stimulating the subjects to express / explain their expertise and knowledge acquisition is the process of extracting, transforming, and transferring this knowledge to a computer program.

5.1.2 The diagnostic *'system'* comprises a number of human and equipment sensors which capture information used for the diagnostic process. These sensors include both the people who observe and interact with the patient – such as family and the nursing and medical staff - and testing equipment, for example blood pressure (BP) or electrocardiogram (ECG) monitors.

5.1.3 Objective, quantitative (numerical) data from *'cheap'*, easily available and immediate sources, such as measurements of temperature, respiratory rate, oxygen saturation or BP, rarely provide sufficient information by themselves to reach a diagnosis. More restricted, resources - particularly advanced imaging, such as CT scanning - can provide an almost immediate and unequivocal result. Somewhere in between lie blood tests and plain X-rays which are also subject to a degree of delay in obtaining results. ECG recording is unusual in this respect, being both relatively complex but readily available, easy to apply and potentially diagnostic.

5.1.4 Less-objective, qualitative (non-numerical) data - for example, history and examination - are used to direct the application of the quantitative testing described above, often being used in a screening mode, which may or may not yield results. However, in some instances such as in major trauma, imaging is now used for screening and near whole-body CT scans are almost routine because the facility is widely available and rapidly diagnostic.

5.1.5 Qualitative data are also deployed for decision making in a more mechanistic way through the use of algorithms, decision trees or checklists, such as by NHS Pathways or triage systems. Although this approach can be generally successful for prioritisation, there is the risk that it might detract from more holistic (looking at the whole picture) judgments and assessments of a patient, in this case effectively labelling Richard *'as if'* he had an acute myocardial infarction (AMI).

5.2 Negative cues

5.2.1 In Richard's case, once the initial pain had subsided, what remained were a variety of indicators associated with the often subtle effects of the dissection. Although he did not feel well, the quantitative data - BP, heart rate, ECG, chest X-ray (as interpreted) and most blood tests - did not provide any clear indication of a specific problem. At this point, there was a risk that he might have been sent home, particularly as there was still the musculoskeletal diagnosis apparently available.

5.2.2 The absence of cues or negative cues[51] can create a challenge for ruling diagnoses in or out and, in Richard's case, the process now rested, albeit temporarily, on the qualitative assessments of little pain and *'looking well'*. The significance of the initial chest pain had not been recognised and the contextual cues of what was normal for this patient, his concerns and those of his partner, as well as changes over time, were apparently given relatively little attention.

5.2.3 This type of contextual information is used clinically and is often given significant weight in paediatric medicine but, when dealing with adults, it may either be given less attention than more objective measures, or considered unreliable or too variable and dependent on the clinician's highly subjective judgement of the patient.

5.3 Changes over time and diagnostic tempo

5.3.1 The role of time in the ED is interesting. The patient's medical problem evolves over time and the way in which those changes are monitored and documented varies. The clinical personnel are pushed and pulled in different directions in the busy ED; there is a time standard against which the performance of the department is measured, there are time delays obtaining resources and getting results and there are overlapping time frames for each member of staff's shift.

5.3.2 One result of this was the difficulty the investigation encountered in piecing together the narrative from the records and the interview evidence.

5.3.3 When signs and symptoms subside or cease to evolve and are accompanied only by non-specific quantitative data, there is the potential for a patient to fall into a diagnostic limbo as staff are pulled to other cases (perhaps with more obvious or specific indicators) or care is handed over to someone else as they go off shift.

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[51] The term *'negative cue'* has also been used to denote cues with a negative meaning. For example, in assessing whether a person has bad intentions, if the person is shouting obscenities, this may be perceived as a negative cue. In addition, negative cue can be used to denote a cue which contradicts a particular interpretation of a situation. For example, *'shouting obscenities'* may be perceived as a negative cue with respect to the assessment of a person as approachable.

5.3.4 In Richard's case, the severe initial pain subsided rapidly and became perhaps almost a historical footnote in the patient record. Although Richard was initially described as looking well, over time this was subsumed by increasing unwellness, anxiety and distress as pain, vomiting and diarrhoea evolved, although the time course of this is not explicit in the record.

5.3.5 From the brief observations and discussions with ED staff which the investigation was able to undertake, it is unclear what triggers or prompts are used to maintain the diagnostic momentum. The diagnostic process moves to the beat of the diagnostic tests which are requested, conducted, and reported according to different time frames depending on which tests are requested. Patients are assessed, tests are requested, and it appears that the patient is often then left until the results come back.

5.3.6 This tempo dictates the diagnosis to an extent. If tests (including observations) do not show abnormal results or results which clarify the diagnosis, it is unclear what then moves the diagnostic process along. In an environment with competing demands, there is the potential to *'lose'* a patient for small periods of time. The electronic patient record (EPR) system provides time-based prompts for observations (which should occur at regular, timed intervals depending on the classification of the stability of the patient's condition) and prompts also appear on the EPR screens when test results become available – it is a *'pull'* system (that is, clinicians must refer to the screen to collect information) rather than *'pushing'* notifications of overdue observations, for example.

5.3.7 The four-hour standard[52] clock is also constantly ticking, providing an additional impetus to move the diagnostic process along. It is not clear whether this played any part in Richard's care as none of the interviewees identified the four-hour standard as influencing their decisions, even when asked directly. The medical specialist registrar (MSpR) said that the transfer of Richard to the ward would be usual, both to avoid breaching the ED four-hour standard and because he was now under the care of the medical team.

5.4 Clinical suspicion and perceived urgency as a driver of the diagnostic process and escalation

5.4.1 From the accounts given to the investigation, the extent to which people were worried about Richard and therefore the urgency with which his case was treated is not always clear. From his partner's perspective, he was acting atypically, even compared to previous illnesses and her suspicions were highly alerted. There were also apparent discrepancies between the levels of concern or suspicion described retrospectively and the actions that were taken at the time. However, given the nature of human memory and what is known about human factors relating to recollection, this is hardly surprising and in no way reflects unfavourably on those who assisted the investigation by taking part in interviews.

5.4.2 The role of clinical suspicion, how it is developed, recorded and reported, and particularly how it is communicated across the wider clinical team deserves some attention, particularly in these hard-to-diagnose cases. When and how should a suspicion or uneasiness about a patient be flagged up to others in the clinical team? What should or can be done about it? How often would it lead to false alarms compared to successful diagnoses not flagged up by objective clinical data? In summary, when should suspicions be trusted, and how should they be acted on?

5.4.3 The qualitative, subjective assessments of both clinical staff and those accompanying the patient form an essential part of the information set available to support the diagnostic process. We need to understand how this information is used to support diagnosis and how it could be better utilised in hard-to-diagnose cases when the objective data are not helping or may be masking a problem.

5.5 Distributed cognition – technology and people

5.5.1 A particular challenge in the complex environment of the ED is that the diagnostic process is distributed across multiple people and technologies. Diagnosis is not just supported within one person's head. It relies on information held in and displayed by technical equipment and information

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52 NHS England sets a standard that 95% of patients attending an ED must be discharged, admitted as an in-patient or transferred to another healthcare provider within four hours of arrival.

held by many people, including family and health workers, who observe and interact with the patient during their time in the ED. The latter also transfer the information between themselves over time. There is no one place where all the relevant information resides, and no one *'processor'* where all the relevant data can be analysed in a rigorous, logical or systematic way. Therefore, the diagnostic process, although ultimately the responsibility of the designated clinical lead, is a team effort.

5.6 Team decision making, coordination and responsibility

5.6.1 The challenge for the ED is not only to make full use of sensors in the environment but to use the data effectively to create an *'information space'* which supports the diagnostic process. This may currently be inhibited by a number of physical, organisational and time-related factors, perhaps including rank gradients[53], designated roles and functions, and the way that the technology is designed and used.

5.6.2 As the collective body of knowledge about a patient accumulates, there are requirements for coordination and sharing information between various information-holders, both the people and the technology. This applies not only to the information itself but also to assessments, plans and actions based on that information.

5.6.3 These coordination requirements are not always dealt with effectively, either by the way the technology holds, processes and presents information, or by clinical decision-making activities, formal and informal briefings and handovers. Although there may be functions built-in to the ED department processes (including by its technology), it is not always clear at each stage in the journey, who is responsible for, and in overall control of, the care of the patient and who leads, initiates or approves the decisions on action.

5.6.4 As in Richard's case, when the potential indicators and behaviours which support an understanding of the patient's condition and drive actions are not clear data points or do not have a clear significance to the diagnosis,

effective team decision making becomes even more important.

5.7 Expertise and experience in the emergency department

5.7.1 People are the most critical resource in the ED. EDs are complex and practice has evolved over years, incorporating efforts to streamline operations and improve effectiveness by redesigning roles and functions, ways of working and so forth.

5.7.2 One of the biggest challenges is the appropriate allocation of experience and expertise to the level of problem being faced. In a case where the diagnosis is not straightforward and where *'diagnostic momentum'* is stalling, there is a point at which the system has to recognise that this has occurred and generate a way to move forward.

5.7.3 The allocation of experience across the tasks required in the ED at any one point in time is a critical function but it is not clear how those decisions are made and the strategy is likely to vary between organisations. At the very least, it requires individual awareness of one's own abilities and limitations, an understanding of what other experience is available to pull in and a culture which supports asking for and giving help without judgment, in the interests of patient care.

5.7.4 Experience, when tempered with self-awareness and humility, provides a critical resource to support the system in dealing with the uncertainties, ambiguities, complexities, weak signals, opportunities and constraints offered by the ED at any point in time.

5.7.5 In this case, the MSpR provided the critical push to move the diagnosis along, in part based on recent experience of a previous patient with acute aortic dissection and in part by having to take on the handover from the foundation year 2 doctor of a *'stalled'* patient. This was initiated by the emergency medicine consultant, who had been unable to assess Richard first-hand or bring his clinical experience to bear. Experience and expertise are resources in limited supply which need to be managed in order to meet the ED demands at the time.

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[53] Rank gradient refers to the *'power'* difference between different job grades, which might generate inhibition with respect to sharing information, speaking your mind and so forth, for fear of repercussion which may occur because one person has power over another based on their job grade. For example, not sharing non-specific suspicions without clear evidence for fear of being accused of crying wolf or getting it wrong, with the potential for loss of reputation or other forms of explicit or implicit *'punishment'*.

5.8 Competing demands and trade-offs in the emergency department

5.8.1 The ED is a system where resources (such as time, money, staff and diagnostic testing equipment) are often scarce, meaning that many of the activities compete in some way, presenting dilemmas for the staff about how to proceed.

5.8.2 The *'efficiency / thoroughness trade-off'* identified by Erik Hollnagel is a classic example of trade-offs common in complex systems (Hollnagel 2017). In such systems, there is always a balance between being thorough and being efficient and you cannot do both. Quite apart from practicalities, patients cannot be subjected to every test just in case (thoroughness), because the priority is to quickly identify life threatening issues, stabilise the patient and move them on to the correct specialty (efficiency). Every patient cannot be seen immediately or be treated exclusively by a consultant or specialist.

5.8.3 Especially in the hard-pressed EDs of the current NHS, the streaming and triage processes reflect this trade off and present best practice for negotiating the trade space. Other heuristic methods and context-specific strategies are also developed to manage these trade-offs in the ED and there is no optimal or best solution. John Flach, another well-respected psychologist specialising in human-systems performance, has described these processes in the context of Lindblom's ideas on *'muddling through'* as strategy (Flach 2012; Flach et al. 2017).

6 Summary

6.1 The ED is a classic example of a complex human-technology system designed to effectively sort and manage a range of clinical problems, from the critical to the minor. Resources of time, equipment, and expertise are often in high demand and not always available when needed.

6.2 While generally appearing to operate effectively in moving patients through, the system is occasionally severely tested by hard-to-diagnose cases in which performance trade-offs are the norm and where diagnostic momentum can sometimes stall. Using a one-step-at-a-time approach to *'muddle through'* the complexity and uncertainty may be the only way to do this.

6.3 A more detailed understanding of the trade-offs and decision challenges would help us to understand where the system is being stressed and to explore ways to support improved decision-making performance. This would look at both human-to-human interactions (such as sharing information, sharing suspicions, shift handovers, making the most of available experience and expertise and working with patients and their families) and human-technology interactions (including alerting systems, data push and pull, sharing test results between remote locations, and providing access to remote support).

6.4 Investigations into tragic events, such as this case of delayed diagnosis of acute AD, can provide insights into issues highlighted by an individual case, but are no substitute for the systematic observation and study of the whole system as it operates, both successfully and otherwise. This would allow the analysis of thinking and decision making in the ED to evolve, increasing our ability to make sense of this complex system.

Appendix 4: List of abbreviations

AAA	Abdominal aortic aneurysm
AAS	Acute aortic syndrome
ACS	Acute coronary syndrome
AD	Aortic dissection
AMI	Acute myocardial infarction
AMU	Acute medical unit
APTT	Activated prothrombin time (see list of blood tests at Appendix 2)
BP	Blood pressure
BPM	Beats per minute
CRP	C-reactive protein (see list of blood tests at Appendix 2)
CT	Computed tomography
CTA	Computed tomography aortogram
CTR	Cardiothoracic ratio
CXR	Chest X-ray
ECG	Electrocardiogram
ED	Emergency department
EPR	Electronic patient record
ESC	European Society of Cardiology
GP	General practitioner
HES	Hospital Episode Statistics
HR	Heart rate
HRO	High reliability organisation
HSIB	Healthcare Safety Investigation Branch
IRAD	International Registry of Acute Aortic Dissection
ITU	Intensive therapy unit
IV	Intravenous
LFTs	Liver function tests (see list of blood tests at Appendix 2)
mg	Milligrams
mmHg	Millimetres of mercury
MRI	Magnetic resonance imaging
MTS	Manchester Triage System
ng/l	Nanograms per litre
ng/mL	Nanograms per millilitre
NICE	National Institute for Health and Care Excellence
O/E	On examination
ONS	Office for National Statistics
PACS	Picture archiving and communication system
PE	Pulmonary embolus
PT	Prothrombin time (see list of blood tests at Appendix 2)
RCC	Regional cardiothoracic centre
RCEM	Royal College of Emergency Medicine
RR	Respiratory rate
SHO	Senior house officer
SpR	Specialist registrar
TEVAR	Thoracic endovascular aortic repair
TOE	Trans-oesophageal echocardiogram
VTE	Venous thromboembolism

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