Wednesday, 17 May 2023

(10.00 am)

LORD BRACADALE: Good morning Professor Freemont.

A. Good morning, sir.

LORD BRACADALE: Your evidence will be taken by Ms Grahame, Senior Counsel to the Inquiry, whom you have I think already met.

A. I have, yes.

LORD BRACADALE: Would you now take the oath in Scottish form by simply -- remain seated but raise your right hand if you will and say the words after me.

PROFESSOR ANTHONY FREEMONT (sworn)

Ms Grahame.

Questions from MS GRAHAME

MS GRAHAME: Good morning.

A. Good morning.

Q. You are Dr Freemont, Anthony Guy Freemont, and what age are you doctor?

A. I'm 70.

Q. You are a consultant in osteoarticular pathology and I wondered if you could briefly explain what that actually is.

A. Yes, I'm a histopathologist and in histopathology there are a number of different subspecialties and osteoarticular pathology is one of those and during my

working life I worked with just deceases of bones and joints and that's where the osteoarticular comes in.

I was slightly more specialised than that sounds in that I dealt just with what's called medical pathology, so the pathology of arthritis, the pathology of metabolic bone diseases and the pathology of fractures rather than tumours.

Q. Right, and as I understand it there are not many who work in the field of that speciality, if I can call it that?

A. No, I was the only one who worked in just medical osteoarticular pathology in the country and around the country other osteoarticular pathologists, there might have been five or six of us.

Q. And when you say the country, you mean the whole of the UK?

A. The whole of the UK, yes.

Q. And in the circumstances that we're interested in, we have heard evidence already in the Inquiry from Dr Shearer, who is a forensic pathologist, and she indicated that there had been a fractured rib --

A. That's correct, yes.

Q. -- after she carried out the initial post mortem it was discovered. We will come to that later today. But I think that was why you were brought in, to give advice

about that fractured rib.

A. Yes. It was usual for paediatric pathologists and Home Office pathologists to send what they believed to be fractured bones to my laboratory, so although I didn't undertake post mortem examinations, I used to receive really from the whole country pieces of bone where pathologists were concerned that there might have been a fracture.

Q. And they would come to you to get your specialist advice --

A. That's correct.

Q. -- on those matters?

A. Yes.

Q. Thank you. And so just over the years, how many fractures would you say you have looked at?

A. Oh, thousands. I can't remember, but, yes, yes.

Q. Thousands in your career?

A. Yes, yes.

Q. Can I ask you to look at something for me please. It's an Inquiry statement and I think you were asked to give a very detailed statement about your involvement in relation to these matters and that is SBPI 00310 and we will see -- you will see that that comes onto the screen in front of you and it is headed, "Witness statement Professor Anthony Freemont", and it was taken on

15 December 2022 and Friday 6 January this year.

A. That is correct.

Q. Before I begin asking you questions about this, I see you've got the folder in front of you. Now, you will have a hard copy of this document and we have tried to provide you with hard copies of everything that you might find helpful.

A. Thank you.

Q. So if you prefer working from hard copies, and many witnesses do, feel free to just simply look through it and refer to it as you wish.

A. Okay. I'm quite happy with this.

Q. In addition we have it coming up on the screen so that everyone can see what we're looking at.

So first of all we've got the Inquiry statement and I wonder if you would -- it's 45 pages long. Would you look at the final page please. We will bring the final page up on the screen and here you will see just beneath paragraph 154 that the date that's given is 20 April 2023 and that's the date that you signed your Inquiry statement.

A. Yes.

Q. Now, you will see on the screen your signature has been redacted so no one can see that publicly, although I think your hard copy might have your signature.

A. It does.
Q. But you signed every page of that statement, as I understand it?
A. I did, yes -- electronically, but yes.
Q. I think since COVID arrangements have been made to allow people to do that.
A. Yes.
Q. Can we see paragraph 154 please. It says:

"I believe the facts stated in this witness statement are true. I understand that this statement may form part of the evidence before the Inquiry and be published on the Inquiry's website."

And I think you understood that when you signed the document?
A. I did, yes.
Q. So you understand that this will be available for the Chair to consider at length and it will also be made available to the public and be published on the website as well --
A. I understand.
Q. -- after you have given evidence.
A. Yes.
Q. Thank you. And we have all of your details in this statement and so I don't need to take you through that at length, but in anticipation of you giving evidence

today I understand you have prepared some PowerPoint slides --

A. I have.

Q. -- which will assist you in sharing your knowledge with the Chair; is that correct?

A. Yes.

Q. Would you look for me please at SBPI 00324 which should be 29 slides which you have prepared on our behalf.

A. Yes.

Q. What I plan to do today, Professor, is just simply go through each of the slides and ask you additional questions about that, but obviously the Chair has your full Inquiry statement as well and he has your full report, so he can look at all of those items.

A. Okay.

Q. Let's start with the first slide, if I may, and it says, "Professor Anthony Freemont", and I apologise, I think I accidently called you doctor when I first spoke to you there. I hope you haven't taken any offence at that.

A. None whatsoever, no.

Q. Thank you. We see a lot of qualifications listed. I wonder if you could help the Chair just understand a little bit about your background, if you could tell us.

A. Yes. When I was at medical school I was offered the

opportunity to take a year out and I undertook a BSC in human anatomy. That was at the University of London.

Then I went on and completed my medical education and that's represented by the MB.BS, bachelor of medicine, bachelor of surgery. I also at that time took the examination for membership of the Royal College of surgeons, which is MRCS and passed that.

I continued working as -- or I started working as a physician at the University of Leicester and while I was there I took the examinations that are necessary to go on to become a consultant in medicine, a physician, which is MRCP, and then I moved to Manchester to become a histopathologist. I moved there because I had always had an interest in diseases of bones and joints as a physician and there was a very highly specialised pathologist there and so I moved into his group and he trained me in bone and joint pathology.

While I was with him I undertook research which led to the doctorate in medicine. In America MD is just the title given to someone who has graduated in medicine. In the UK it's a directorate degree, it's the medical equivalent of a PhD, and so I was awarded that and then I took my examinations to become a consultant in pathology, in histopathology, and that's where the MRCPath came from.

Q. Then I see that you are a fellow of certain Royal Colleges.
A. Yes.
Q. Tell us which Royal Colleges you're a fellow of?
A. Okay. Well, once you have reached a sort of consultant status, and particularly if you're a researcher, the Royal Colleges will look towards -- I suppose rewarding is a good word, look towards rewarding continued development and contribution to the specialties and one of those Royal Colleges was the Royal College of Pathologists so they made me a fellow of the Royal College of Pathologists, but as I have explained I undertook a lot of my work in the medical area of pathology and so two Royal Colleges of pathology -- sorry, of medicine, of physicians, awarded me fellowships, so fellow of the Royal College of Physicians of the United Kingdom, that's based in London, and a fellow of the Royal College of Physicians of Edinburgh, because I used to do a lot of work with the rheumatologists here in Edinburgh.
Q. And as I understand it, not everyone can become a fellow. It's not like membership where you pay your money and join, you actually -- it's recognition of your speciality?
A. It is, a real contribution, yes.

Q. Thank you. So you're a member of three Royal -- a fellow, sorry, of three Royal Colleges.
A. Yes.
Q. And then it says that you're a Professor of Pathology at the University of Manchester. Can you explain to the public what it means that you're emeritus?
A. Yes, that means that I have retired and because of the contribution that I made to the university -- I worked at Manchester University for 40 years, I was a leading researcher and I also ran the medical school for some time as well. As a consequence of that when I retired I was awarded emeritus status which means that although I'm not an employee of the University of Manchester I have all the rights and privileges, so I can continue to do research, I can use the library facilities and so on. So that's what that means.
Q. And is that a benefit that you continue to enjoy today?
A. Oh, yes, yes.
Q. Am I right in saying -- we will come to your CV in a moment, but you retired in 2021. Actually I see it is at the bottom of this slide:

"... on retirement..."

A. Yes, I did. I retired from the university in 2021. Half of my work was always for the National Health Service and I retired from the National Health Service

in 2018, so I stopped being a consultant in 2018. I carried on working for the university in a sort of research capacity until 2021 and I retired then because I had leukaemia and I knew I was about to start treatment so that's when I retired.

Q. I'm very sorry to hear that.

A. It's fine.

Q. And then at the end of your -- this slide it says you're a Proctor Professor of Pathology. Can you explain to people what that means?

A. Yes, there's a hierarchy of Professors, nationally and locally. The highest of those is a Regis Professor and then the next level down as it were is a named chair. That means a chair that's been endowed to a university and that's where the Proctor came from. It was a Professor Proctor who endowed the chair in pathology, so that was a named chair. I still kept my official title of Professor of Osteoarticular Pathology and because of the work that I was doing from my retirement from the NHS until 2021, I was also a professor of Biomedical Egyptology.

Q. So a number of other accolades or acknowledgement of your status there?

A. Yes.

Q. So Professor of Biomedical Egyptology, what does that

involve?

A. In Manchester, because of the very rich people who were responsible for the cotton industry, a number of these people went off to Egypt and brought back mummies, and a lot of mummies, and they are housed in the Manchester Museum, which is part of the university. When I was -- towards the end of my career, when I was both a consultant and a university Professor, I was funded by the Medical Research Council to undertake a lot of research into how new tests could be designed and then introduced into the National Health Service and we -- the university then received an endowment from a wealthy lady who was very interested in Egyptology itself and I was asked if some of the technologies that I applied in my NHS and university work, and in particular looking at molecules within mummified tissue, which is partly decomposed tissue, might help us to better understand who the ancient Egyptians were, what their lifestyles were like, how they ate, what they ate and so on, and with this wealth of material that we could access because of all the mummies that had been brought to Manchester, we were able to make some very interesting observations using these new technologies.

Q. That was work you undertook as part of your work at Manchester University?

A. Yes, I had a lecturer who worked with me who was a very, very good geneticist -- I am a molecular pathologist but not a geneticist -- and the two of us worked very well together to build up a pattern of, as I say, who the Egyptians were, what illnesses they had, and because we had so many of these mummies we were able to do statistical analysis that looked at populations as well as looking at individuals.

Q. Thank you. Now, in terms of your CV you have provided us with a copy of a CV. We don't need to have it on the screen. For those who are interested it's WIT 00015 and you also give some details in your Inquiry statement about your career between paragraphs 2 and 7 of your Inquiry statement.

One of the things I noticed was that in July 2021 you were appointed by the Home Office to train the next generation of osteoarticular pathologists. I wonder if you could tell the Chair a little something about that appointment.

A. Yes. During the years that I undertook medicolegal work, usually for the police but also for the defence, I had and developed further an expertise in fractures. It also fitted in with my research where I had funding, again from the Medical Research Council, to look into the mechanisms by which fractures occurred and healed at

both the microscopic level and the molecular level, and for some part of that time there were two pathologists in the United Kingdom working in that area and that was a very equitable arrangement because quite often both the police and the defence would want to have an experienced pathologist working in those areas.

When the other pathologist retired there was just me delivering all the opinions in this -- in the area around fractures and this particularly affected fractures of infants and that really wasn't tenable, so I brought on board another pathologist who I had trained and when I retired he was the only pathologist and the amount of work has increased dramatically and as a consequence -- I mean he was still working as an NHS consultant, he is still a university Professor, and he was trying to cope with all of this work and a large backlog built up, a backlog of ten months, and of course this was at the same time that we had lockdown and things were all that little bit less well oiled as the system works as a consequence.

So I started to write-up all my experience as scientific papers so that pathologists like Home Office pathologists or paediatric pathologists could look down the microscope at fractures and using algorithms which I developed, they could have predicted the data

fractures. But they were naturally cautious about doing that because they didn't have the sort of background that I had, aging fractures varies in infants and adults and adults of different ages, people with different medical diseases as well, so that didn't really relieve the pressure on my colleague, or my colleague before I retired, and I was contacted by the Home Office in 2021 and asked if I would come back to work. And I live close to an orthopaedic hospital and they were prepared to do the preparation of the tissue sections and so on and -- but I explained to them my medical problems and they said, well, would I be prepared to train another pathologist so that we were back with two.

So I started that person's training. I then unfortunately became ill with COVID last year and spent a lot of time in hospital but I had given him the background and the basics and he then went to work with my other colleague and is now fully qualified as an osteoarticular pathologist.

In the meantime I have taken new cases so that the -- my pathology -- my original pathology colleague would then be in a position to clear his backlog and I'm still taking new cases from the police and from defence lawyers as well and I have done that really, apart from this spell in hospital, for two years now -- well,

a year and a half.
Q. I think I have read in your CV that you have -- in England and Scotland -- written over 400 medical legal reports over your career?
A. Yes, that's correct.
Q. And you have been appointed, as you say, by both prosecution and defence?
A. Yes.
Q. Have you also been appointed in civil cases?
A. Yes, but not very many. I have done a lot of work in the Family Court, obviously, because of fears for the safety of siblings. So yes, I have covered most courts.
Q. And I understand from your CV that you have given evidence in court or in inquiries more than 150 times?
A. Yes, yes. This is over a long time, but yes. Yes.
Q. Yes. And you are published, you have published articles and been involved in the publication of books and articles?
A. Yes. I have more than 300 published articles. I have lost track of how many book chapters I have written, but -- and of the 300 articles more than 80 reflect directly on fractures: fracture healing, the mechanisms by which fracture occurs, and then how that can be recognised pathologically and that also makes up a number of the chapters that I have written.

Q. If we move on to slide 2 do we see one of the -- as I understand it you contributed a chapter to the book "Investigating the Belfast Mummy", is that correct?

A. That's correct, yes. This is -- there's -- as well as being able to look at large populations, the sorts of techniques that I have employed in looking at mummies, and in particular into the decomposed tissues, are applicable to understanding individuals and that gives you a little sort of snapshot of how people were. This lady is known as Takabuti. The top of the two right articles looks at her maternal genome, so this is the DNA that she has that comes through her maternal line and this, this haplotype -- it is just a name -- of H4a1 is an interesting one because it has only ever been described previously in Central Europe and particularly in Germany in relationship to a group of people known as the Beaker People because of the artefacts that they left behind and from that and some of the other molecular work we have done we were able to show this maternal lineage being integrated into the sort of rich areas of ancient Egyptian society and when my Egyptological colleagues saw this they were able then to piece together interesting stories -- I'm -- I don't mean that as untruths, but stories, around how women were integrated -- women from elsewhere within Europe

were integrated into this very rich society of people living along the Nile valley.

We were also able -- and, sorry, that's what the bottom paper talks about. It's a new word that we invented which is the paleobiography, so this is learning about a person and then using that to better understand what was going on in the world at the time, or at least in Ancient Egypt at the time.

We were also able to piece together her last few hours of life. Some samples were taken from her muscles which I analysed using molecular techniques, which showed that she had been running for at least two hours prior to her death and when we looked at the mummy in more detail using very clever imaging techniques, we were able to show that she had been killed by a bronze axe, and nobody had known about this, despite the fact that the mummy had been in Belfast since I think 1823, and we were able to demonstrate how she died and this happened to coincide with the time when Thebes, which was where she was from, was under attack from external forces. So I think with all of that information we were able to piece together the fact that she was being chased through the streets, probably by a soldier because she was eventual killed with an axe, at a time when Thebes was being sacked, so an interesting way of

looking at who these people are and even little nuggets like that one showing, you know, what life must have been like in a sort of war-torn area like that.

Q. And a moment ago you talked about mummified tissue and decomposed tissue and I know that that's relevant to the circumstances we're looking at today. Can you explain briefly the differences between normal tissue and decomposing tissue and mummified tissue?

A. Yes. Normal tissue has a structure to it. It has live cells within it and down the microscope you can see the cells, you can see the structure of the tissue. As decomposition sets in -- and decomposition can be a generalised decomposition or a very focal decomposition -- you get invasion of organisms, many of which come from yourself, we have a lot of bacteria that live in our bowels for instance and they can break out and about and start to damage the tissue, and a lot of fungi as well, we have fungi in our mouths and so on all the time, and they can infiltrate into the tissues and start to destroy them.

One of the tenets of Egyptian life was that you would go to the afterlife if you were good and you passed the test, and if that was to be the case then your body would need to be preserved and that was why in cases like Tutankhamen there were so many artefacts put

in with the body as well, because they would be used in the afterlife. And in order to prevent breakdown of the tissues, the Egyptians used mummification techniques. What they hadn't realised is that although the exterior of the body looked perfectly normal, there was still some decomposition that had occurred in the tissue during the time of mummification, even though they removed all the internal organs and put them into special jars and things, these tissue were decomposed.

So one of the things that we had to do in order to begin to study what led up to these papers and these chapters in the book were to see what molecular techniques could be used in identifying different types of tissues that had -- and the processes going on within them -- that had occurred during decomposition and in looking at medicolegal cases quite often bodies take a little while to be discovered, or they are buried and when those tissues were sent to me I used the same techniques as I later used in mummified tissue because they are sort of comparable.

Q. Thank you. So you're using similar techniques --

A. Yes.

Q. -- depending on what type of tissue it is and how long it has been decomposing?

A. Yes.

Q. Can we move on to the next slide please and this is where you begin to talk about the initial report on Mr Bayoh's isolated left first rib fracture.
A. Yes.
Q. And I think when you were first approached by the Crown Office you were sent a letter of instruction.
A. Yes.
Q. I don't need to go to that but for those who are interested it is dated 16 March 2017.
A. That's correct.
Q. And it's COPFS 03578. I think the Crown explained to you, when they first got in touch, that there had been a post mortem on 24 May 2015, that there had been -- an x-ray, a skeletal survey and a CT scan had been carried out and then -- and the skeletal survey was 27 May, the CT scan was 28 May, I think.
A. I think the skeletal survey was done before the first post mortem and then a new study was undertaken.
Q. Sorry, yes, and then it was later. And they were interested in attempting to clarify the role -- this is Crown Office -- that restraint played in Mr Bayoh's death and they said:

"It was clear the apparent fracture will not have caused the death but it may be significant re establishing the force and mechanism of restraint used

by officers."

A. Yes.

Q. And I think it is fair to say from my reading of your statement you agree that the fracture did not cause or contribute to Mr Bayoh's death?

A. That's correct, yes.

Q. And I think we heard last week from Dr Shearer, the pathologist, that she also took that view.

A. Yes.

Q. Then you prepared a draft, an initial draft, on 3 May 2017 and a final report on 3 July 2017?

A. Yes.

Q. And the number of that is COPFS 00037. And if we could maybe move on to the next slide. So we have heard that the rib that was fractured was the first left rib.

A. Yes.

Q. And you were given that information, you were given some information by the Crown about possible causes of that fracture and you were asked to reflect on this and give your views.

A. Yes.

Q. Now, this slide -- I'm hoping you will be able to explain to us where exactly is the first left fracture and what these images show.

A. So there are four images here. The top left-hand image

shows in red the position of the two first ribs, the one on the left and the one on the right. As you can see they're rather different from the other ribs in that they really form the base of the neck, and what's also been put onto this image in a sort of background is the distribution of fat and skin and muscle that gives rise to the shape of a body and you can see here that the first ribs are for quite a lot of their length higher than the shoulders.

The right-hand top image shows what in medicine we would call the relationships of the first rib to the other ribs and to the other bones in that area.

The first rib at the front is closely related to -- well, touches the clavicle, the collar bone, and that's the bone that you can see going from within the red circle out towards the shoulder.

Q. We have a facility on our screens and it allows you to touch the screen -- you can either use -- touch it and get a red circle, or you can touch it and get a line if you drag your finger along the screen and I wondered if you could identify for us, by maybe using a line, the clavicle that you're describing?

A. Yes, this is the clavicle.

Q. And if you make a mistake, don't worry, we can delete it.

A. It's a bendy line I need, but I think that indicates the line of the clavicle and you can see that it's not a straight bone but --
Q. It's not a straight bone and it goes from the front of the neck --
A. Yes, that's correct.
Q. -- to the top of the shoulder?
A. Yes, it starts from the top of the breast bone, so it starts about here (indicates) and it goes up into the neck.
Q. And the first rib, looking at the image on the top right-hand side, does it go from the front underneath the clavicle?
A. It does, yes. It goes underneath the clavicle and then goes upwards towards the spine and the spine, if I can just touch it, is -- is there.
Q. Do you want to try that again? There it is.
A. Yes, so number 2 is the spine. The spine is made up of blocks of bone called the vertebrae and we can see two vertebrae there surrounding -- well, inside -- parts are inside that circle. They also have bits that stick out at the sides which are known as the ala or wings and the first rib articulates -- it has a joint with the ala of the vertebra just there (indicating) and again just here (indicating) where it touches the body. Sorry, that's

not quite in the right place. So there are two joints at the top of the rib.

Q. Without wanting to make it more complicated I wonder if you could identify for us the second rib and if we can get a squiggly line that might -- no, we won't be getting a squiggly line. We appreciate it may have limitations but --

A. If we start here ... (indicating)~...

Q. That's it, yes, I can see it on the screen.

A. Oh, right, it hasn't come up on mine --

Q. If we're looking towards that image, towards the bottom there's a white area?

A. Yes, the ribs join onto the breast bone with a piece of cartilage. It's not quite the same as a normal joint like the elbow or the wrist.

Q. Right, and that's why it appears in the top left-hand image the red line doesn't go all the way to the sternum?

A. Yes, that's correct.

Q. You were pointing to the bottom of that image, if you just point to that again, is that the start of the second rib?

A. That's the start of the second rib there.

Q. Thank you. And that again appears to go under the clavicle, is that right?

A. Yes, it passes under the clavicle and then curves round and then goes underneath the first rib where it joins onto the spine, so I have a number 4 on my screen. It's immediately below the number 4, I mean behind the number 4, that it joins to the spine.

Q. Right, thank you. Then can you tell us about the images on the bottom of this slide?

A. Yes. The left-hand picture is a drawing of the right-hand side of the neck and the clavicle is right underneath the -- the collar bone is right underneath the skin, just there, and you can follow it along and then there are muscles that run up the neck, they join about here (indicating), but if you look below you can see that the muscles are running from the end of the clavicle nearest the breast bone up into the neck. And behind all of those structures -- and you can feel it in yourself -- is a large chunk of muscle which comes from the scapula, the shoulder blade. That is demonstrated in the right-hand image. I have removed the name of these various muscles which is why we're left with the little black lines.

On the left-hand side are the muscles nearest the skin at the back, so we're looking at the body from the back here, and you can see this huge muscle which goes up into the back of the neck. That's the same muscle

which we can see here from the front in the left-hand diagram and between that muscle and the scapula, the shoulder blade, the collar bone and the muscles going up into the neck, we have a little sort of dinge, a little triangular-shaped hollow and I have tried to demonstrate that using a triangular-shaped bowl because, as we have seen from the top right-hand image, over a lot of its length the first rib is associated with other structures, other bones: at the front with the collar bone and at the back with the second rib and the wings particularly of the vertebrae. But there is a little area where it is all by itself and that happens to be in the bottom of the bowl that I have drawn there and I did that because in the previous slide I had put in bold the words "Isolated" and "First rib" and isolated means that -- in this context means that it is only this rib which has been damaged, none of the other bones adjacent to it, and that has a lot of important meanings. It can be damaged -- we will see this later -- by a direct blow, but that direct blow has to go right down to the bottom of that triangular hollow, so I put this diagram in really to show if the bone had been broken by a direct blow, the sort of area that you would be looking at for that blow to have occurred without damaging any other bone.

Q. So just to go through -- if we can go back to the bottom left-hand image, we see the little bowl that you have captured there. Can you point, on the diagram of the person's neck, to where that bowl would be positioned please?
A. Can I do a triangle out of three straight lines? Would that work, do you think?
Q. Yes, I understand that you can, yes.
A. Okay, so it's ... (indicates).
Q. I think you will have to take your finger off the screen -- that's it.
A. Yes.
Q. So between 7, 8 and 9 you have drawn a triangular shape?
A. Yes.
Q. And that's the area where there would be this -- you are using the analogy of a bowl?
A. Yes.
Q. And that's the area where I think you said if there was a direct blow it would have to go right into that area?
A. It would, yes.
Q. Thank you. Is the first left rib a very similar shape to the first right rib?
A. It's an identical shape, yes.
Q. Just on different sides?
A. Yes, and obviously the bend is in a different direction

because it's on another -- the other side.

Q. Dr Shearer in her evidence described that area as protected, protected by other muscles and bones and tissue. Would you agree with that description?

A. I would, yes. If we go to the top right-hand picture, the new circle, the new little red circle marked 3 is covered in the muscles that come up from the -- up from the front of the neck. The area at the back, which on the bottom left diagram is represented by 7, is a huge piece of muscle and it's particularly powerful in us because we walk on our hind legs, if you like, so it has to support the weight of our head and all the sort of things that happen to our head.

So this is a huge chunk of muscle and it's attached, as the bottom right picture shows, with this grey area -- I can just do that (indicates) -- to the top of the shoulder blade, so those groups of muscles, the collar bone, and to a certain extent the shoulder blade itself, offer protection in that area, so it would be very difficult for instance, maybe even impossible, to inflict damage solely to the part of the rib where it isn't adjacent to other bones by putting a force, or a blow or whatever that went across those structures, that went across from the collar bone, across the little hollow to the big muscles at the back. They all are

protecting that hollow from physical injury.

Q. And I think you will -- we will come on to it later, but I think the absence of injuries to the muscles or the skin in that area is an important factor for you?

A. It is as well, yes.

Q. We will come on to that.

Let's look on to the next slide please, so this is slide 4. I think here you talk about once you had been instructed by the Crown and you had accepted that instruction to prepare a report, you received six microscope slides with certain staining on them, and that was at the end of April in 2017.

A. Yes.

Q. And you reviewed those as part of your work in preparing your report.

A. Yes.

Q. And I think in your report you had actually mentioned that you also received a tissue block as well?

A. Yes.

Q. Can you explain to the Chair what the significance of these six microscope slides and the staining was?

A. Would it be possible to go to the next slide?

Q. Of course, yes.

A. So this is a very complicated slide, but it's a series of images of different stages in the production of

a microscope slide and you need to follow the red arrows. So with the exception of the top middle and the bottom right image, which are of Mr Bayoh's bones, the rest are there just to demonstrate what we can see.

So the top left-hand picture is the sort of sample that I would be sent. It's a bone, it's a rib and I examine it and I measure it and so on and you can see on that rib -- I will just pop a circle round it -- sorry. Okay, thank you. There's a slightly darker area there. That is bleeding that has come from a fracture and what I would do is I would isolate that piece of bone by cutting it on a saw and that then represents the next image, which is of Mr Bayoh's bones, and we will be returning to that image.

What I would then do is to cut it further, and this is what happened in Edinburgh when the pathologists were making the tissue sections that I was sent. That bone was cut from left to right, as it were from the tip of the left-hand arrow to the blunt end of the right-hand arrow. The calcium was removed and then it was placed by a long and complicated process into paraffin wax, which is known as a tissue block, and the tissue block that you can see on the right-hand top image -- can I --

Q. Yes.

A. Thanks. Yes, that is the tissue block and that contains

the tissue which you can just make out as being a slightly greyer colour, attached to a plastic holder, and the mould that's been used to make that is the metal piece on the person's fingers.

Now we have this tissue block which is three-dimensional, it has thickness and it has two other dimensions as well. In order for the microscope to work and to allow you to see images down it you have to be able to -- for light to pass through the tissue and if you go to the middle right image at the bottom you can see a microscope with its lenses. You can see a piece of glass, that's a microscope slide, and below that a white circle and the light comes from below the white circle, passes through the slide, then up through the lenses to the eyes of the pathologist.

In order to do that the tissue is cut very, very thin and it and its -- the paraffin that's supporting it, the paraffin wax that's supporting it, are round about -- it's 5 microns. If I tell you that a human hair is 70 microns you can see just how thin that piece of tissue has to be in order to allow the light to go through it.

It has some peculiar -- when it is cut that thinly, it has some peculiar physical properties, one of which is that you can float it on a bath of water and the

middle picture in the middle row shows two sections that -- they naturally stick to one another end to end and when they're floated on water they stretch out and you can see one of the sections there and just below it is the other section.

Those tissue sections are then placed onto a microscope slide which is a piece of glass and that has to be very pure glass because the light passes through it and you don't want it to be distorted, but when the tissue is that thin you can't see anything in the tissue at all, so in order to visualise it, it is stained and a lot of these stains people haven't really understood what they mean except that they give very nice colours and colours that tell you about certain structures within the tissue.

In fact it is a form of chemistry, it's colour chemistry, so if we go to the bottom left-hand image you can see different coloured stains that might be used in different settings for staining the tissue and in the slide to its right you can make out that the person is holding between their thumbs and first fingers there a microscope slide and the tissue there has been stained blue.

It is then looked at under the microscope and the sort of image that you see is the image at the bottom

right, and that is from Mr Bayoh's slides.

One way of thinking about the way in which a tissue block is cut, though it's a rather crude way of looking at it, is to think of a sliced loaf, or an unsliced loaf that is then sliced, and the six microscope slides that I was sent were different slices down through that loaf of bread, down through the tissue block.

If we could go back to the previous slide.

So the six microscope slides came from the same tissue block and three of the slides that I was sent have been stained with what's called H&E, which is a mixture of two stains, haematoxylin and eosin, and this is the standard stains that all histopathologists use when they're looking down the microscope at tissue.

In addition, the pathologist had looked for iron and this is a sort of Prussian blue-type stain which is called Perls stain and the H&E slide showed us structures. The Perls stain was looking for iron and it was negative. But what I was able to see down the microscope in the H&E stained slides -- so these are three slides from different levels down through a three-dimensional structure, so what you see in the three sides isn't identical because you're coming down through the loaf of bread and you might come across a hole in the loaf of bread when you're cutting it, or

the shape of the loaf of bread isn't cylindrical. So they're all slightly different but they are from the same piece of tissue and it was quite clear that there was a fracture present, but when I looked at greater magnification I could see that there was tissue decomposition that had occurred to the tissue before it was sent -- before it was processed using the techniques I have just shown you.

Because of tissue decomposition, some of the features that I use to look for bleeding weren't present, but nevertheless there were appearances that I thought did demonstrate bleeding and that the bleeding was into the fracture and more importantly perhaps into the bone marrow and particularly the soft tissues on either side of the piece of bone.

I also saw something in the bone which is called osteocyte necrosis. This is a term that's been used for some time and we now know that the term itself is wrong but I will use it. We need to understand really that osteocyte necrosis is actually not the cells dying because they have been deprived of nutrients, but the cells are actually committing suicide. It's a process that's known as apoptosis and it's an important finding in bone that's adjacent to a fracture line.

The lower two, the bleeding particularly into the

soft tissues and the presence of osteocyte necrosis, indicate that the fracture occurred during life and they are important features for proving that. But although I was certain about the osteocyte necrosis, I wasn't certain about the bleeding because of tissue decomposition and this is where I started to use the molecular techniques that we were discussing with the mummies.

Q. Can I ask you a few more questions about this slide?

A. Of course you may.

Q. You have talked about Perls being a stain to identify iron; why is the presence or absence of iron important in terms of the job that you were trying to do?

A. The red blood cells contain haemoglobin and haemoglobin contains iron and it contains iron in what's called the ferrous state. The Perls stain will only pick up iron in the ferric state, so it has to undergo changes following the haemorrhage before the Perls stain can pick it up and that takes time. So when you do a Perls stain you are really looking to see one of the effects of haemorrhage, but haemorrhage that had occurred several hours, maybe many hours, prior to death.

So the Perls stain was negative, which means that if there was haemorrhage present, if there had been haemorrhage present, that that haemorrhage had not

occurred -- had occurred, rather, closer to death than it normally takes for the body to convert iron from its ferrous to its ferric state.

Q. So the Perls stain is not as sensitive, but it can identify haemorrhage or blood in the stain but it would have to have been there for a number of hours?

A. Yes.

Q. So any blood or haemorrhage that had occurred in a shorter period of time would not be identified by a Perls stain?

A. That's correct, yes.

Q. So the Crown Office stains you were sent, the Perls stain didn't show any haemorrhage or blood in the stain --

A. No.

Q. -- using that test?

A. So it wasn't helpful in the sense that had there been Perls stain there -- Perls staining there, then I know there would have been iron in the tissues, which means that iron would have had to have come from haemorrhage. But if I could demonstrate haemorrhage by another means, then the Perls gives us a sort of time point beyond which the fracture had not occurred. Sorry, that wasn't very good English.

Q. So if the fracture had occurred perhaps the day before

you may have been able to detect that from the Perls stain?

A. Yes.

Q. And -- and you have said at the third bullet point there:

"Appearances suspicious of bleeding into the fracture."

Now, was this something that you were able to witness yourself looking through the microscope?

A. It was, yes.

Q. So despite the negative Perls stain, you yourself could actually see what looked like possible bleeding?

A. Yes, what looked like bleeding but that had undergone decomposition.

Q. Right, and so in light of that, and in light of the fact you could see these signs of osteocyte necrosis, what did that then cause you to -- what steps did you take in light of that?

A. Okay, there were two major questions that I wanted to ask. The first was why there was tissue decomposition. The second was if there is haemorrhage into the tissues, is there a better way than using Perls stain to demonstrate that there had been haemorrhage and in doing that I had to look at the changes in the tissue and say could anything else have caused these changes in the

tissue? So one was excluding and the other one was including whether or not there had been haemorrhage and I think on some of the subsequent slides to the next one I can show you some of the things that I saw.

Q. Let's look at the next slide, if we may. You have taken us through that slide.

A. Yes, I apologise, it was in the wrong order.

Q. No, not at all, and then the next one please. Well, just before we leave that, at the bottom right-hand we see the pink coloured slide -- the image from the pink staining?

A. Yes. The predominant pink staining that you can see there is bone and the bone is very rich in protein and as a consequence stains pink with the H&E stain.

Q. So that's an example of the H&E stain and that's what the histopathologist will do commonly?

A. Always, yes.

Q. Always. Then let's look at the next slide please. This looks, to the right-hand side, like further images of the H&E stains?

A. Yes.

Q. Tell us about the images you have here.

A. Okay. So just to explain these images -- excuse me. Sorry, just to explain these images, they are my attempt to show what bone looks like once it has been sectioned,

so if you imagine that the bone is a cylinder and a thick walled cylinder, the outer part of that is called the cortex and then there is a space down the middle and that contains bone marrow. If you take a section down through that that is very, very thin, you will end up with the two cortices, one either side of the bone marrow, and within the bone marrow, or crossing the bone marrow, are thin pieces of bone which I have tried to demonstrate with those thin blue lines passing from one cortex to the other. So you have lost the cylindrical shape and what you see now are just the two sides of the cylinder and then anything that's in the middle and crossing it.

The third diagram just shows what you might expect to find if there had been a fracture and so the bones were no longer in continuity.

Q. So the zigzag that we see on the bottom left is an image of a fracture -- indicative of a fracture?

A. Yes.

Q. And then the stains we see on the right-hand side, tell us what we see here?

A. Okay, the easiest one to understand is the central image and you can see the two pieces of cortical bone which correspond to the middle of the three left-hand images and you can see also little pink strands crossing it --

crossing the white space between the two cortices and they are this meshwork of bone which is also shown on the middle left image.

Q. Then at the bottom is that simply a close-up of what we see?

A. Yes, so what I have done is I have put the green box around an area that I wanted to show to the Inquiry. If you go to that bottom image you can see all of one cortex on the left and a part of a cortex on the right and little bits of bone which are also this dense pink colour that are part of the bone meshwork that's crossing the bone marrow.

But the purpose of this image is not really to show the bone, but to show the bone marrow itself and -- can I use -- yes, circle.

Q. Would you like a circle?

A. Yes. Inside the circle there is nothing and outside the circle are the edges of a large hole and if you look up to the left and upwards of the number 1, you can see other holes within the bone marrow. Those are not natural holes within the bone marrow.

Many of the organisms that cause decomposition make gas and as they make the gas, the gas expands and particularly in very soft tissues like the bone marrow, it pushes the bone marrow out to the sides leaving these

holes. If I were to show you at much higher magnification you would see also that the cellular structure within that bone marrow has also been lost, it has become -- it looks as if someone has wiped it, and those two features are the features of decomposition that perturbed the way in which I would normally look at aging fractures.

Q. So any sort of gaps or areas of white that aren't stained pink were the signs of decomposition that you were able to identify?

A. That's correct, yes.

Q. And you wanted to ask some further questions about why that exists?

A. Yes, as to what had caused it, yes.

Q. Will we move on to the next slide?

A. Please, yes. I have said that one of the things that I saw was a fracture, so if you can cast your minds back to the bottom of the three left-hand images, the drawings that I have done with the streak of lightening going through them, the left-hand picture shows a fracture from a little distance, it's a lower magnification of the picture on the right, and the green line represents the line of the fracture and to the left of the fracture line and above it you can see a green arrow and that points to a piece of bone which has been

fractured away from the fracture line.

If I could have a straight line. Thank you. That is the extent of the piece of bone -- the bone is a peculiar shape which is why with the straight lines it appears that there are gaps but there aren't, that's a single piece of bone, and everything to the bottom right of that line is also a piece of bone, so the fracture line separates these two pieces of bone and that's effectively what a fracture does.

Q. So there's the cortex on either side of the bone --

A. Yes.

Q. -- which is the sort of more dense pink staining?

A. Yes.

Q. The area in the middle is the bone marrow?

A. Yes.

Q. Again with pink staining. The whiter area towards the bottom -- sort of second half of that image, is that gas from decomposition or something else?

A. No, there is gas there, but it is the normal marrow space, so where the green line goes through the marrow is shown in the right-hand picture because it is not normal marrow.

Q. Can you point to that on the right-hand image?

A. Yes, if you look at the blue arrow and just follow it down, so if I could have a line -- sorry, that's just an

enlargement of the -- the red lines 6 and 7 is the same area as the green line in the left-hand image and you can see that there is very little gas. There's no bone marrow, which is a sort of filigree of blue and pink, and instead there's this very dense pink material below the blue arrow and you can see similar areas either side of the line marked 6, where there is also pale somewhat homogeneous tissue.

One of the features though of the area I'm showing with the green arrow is that it is broken up into lines. That's a process that I call lamellation and haemorrhage as it undergoes decomposition can form this lamella pattern. The lines, however, could represent tissue that has been forced into the fracture crack from outside or -- it is very rare, but as I alluded to earlier, there are fungi that can contribute to the decomposition processes and they have long filaments -- they have rounded bodies and long filaments and of course long filaments could have that sort of structure as well.

So the question I was wanting to ask as far as these two images are concerned is what was the nature of that pink material that filled the fracture gap? Was it some tissue that had been forced in? Was it fungal material? Was it haemorrhage? And if it was haemorrhage, what

components of normal haemorrhage and clot formation were present?

Q. Let's look at the next slide. Is this further examples of the stains, H&E stains?

A. Yes, this is the H&E stain. I said that -- we used this term "osteocyte necrosis" and I thought the Inquiry would be helped if I could demonstrate what I mean by osteocyte necrosis.

So there are two squares on a section that we have already seen previously with the fracture line running through it and if we look at the red square and what that shows, there is pink colouration over most of it and that is the bone, but you will also see little blue spots. The blue spots have picked up the haematoxylin stain, not the eosin stain which is the pink one but the haematoxylin stain which is blue. Those are the cells that live inside bone itself and they are called osteocytes, which just means bone cells. You can see that there is a scattering of blue dots across that piece of bone, so that is normal bone in terms of osteocytes that are contained within it and they live in little holes called lacunae.

When the cells die the lacunae remain, so if we go to the top image which comes from the edge of the fracture -- and I outlined the piece of bone on the

left-hand side -- this green square comes from the fracture immediately -- the bone sorry immediately adjacent to the fracture.

If you look first of all at the pink stain you can see that the bone has frayed. Do you can see there's a little sort of frill along the bottom? This is the way in which at the microscopic level bone fractures, it fractures into pieces and it pulls apart like this.

Q. Would you just point to that on the screen. I think we can all see it, but just in case --

A. Can I have a circle? Ah, if the circle were bigger -- can I stretch it?

Q. I think they can extend it, but that general area where we see the white marks going up into the bone?

A. Yes.

Q. Thank you.

A. Now, if we go into the bone itself you can see two or three blue dots in the bone.

Q. Do you want to highlight those?

A. Yes. Circle again, sorry. I managed to take the line through two of them, but you can see one in the middle.

Q. And what do they show?

A. They show live osteocytes, in the sense that they were alive when the tissue was taken and then all processes of decomposition cease by the way in which the tissue is

processed after that.

If you look at everywhere else in that piece of bone you can just make out white holes. If I -- let's try that. Can you see just understand the circle are two small white holes and if you look at the live cells you could imagine that something of that size lived in those holes and once you get your eye in, all the holes in that area, and in fact in most of this piece of bone, are empty.

Is that clear enough?

Q. Yes.

A. Thank you and that's what's meant by osteocyte necrosis, but, as I say, it isn't necrosis. Normal bone, even after someone has died -- and remember this piece of bone was removed, what, about a month after Mr Bayoh died -- still contain normal nuclei, so the piece at the top reflects cell death that's occurred as a consequence of the fracture and we now know that this is suicide by the cells, this process known as apoptosis.

A lot of my evidence from here onwards will talk about osteocyte necrosis and the number of cells that are present and what that might mean to timing, aging of fracture.

Q. Thank you. Let's move on to the next slide. Here you have asked some -- posed some questions that you asked

yourself. Tell us about those.

A. Okay. So was a fracture present? Yes. I have seen that and I have showed that to you. Could I see osteocyte necrosis, a process that starts in life? Yes, I could.

I wasn't anticipating seeing bone tissue in which decomposition was present, so I have put a question mark next to that because I wanted to know why decomposition was present.

I also wasn't sure that I had seen bleeding -- I thought I had, but I wanted to be more sure, if you like, and the reason that I wasn't able to see the bleeding was because of decomposition. One of the first things that undergoes decomposition are red blood cells and it is looking at red blood cells in tissue that allow us to look for haemorrhage. And I wanted to know not just whether it was present, but also the amount and distribution of haemorrhage. When you get haemorrhage into a tissue -- and we might best recognise this when we get haemorrhage onto the surface of our skin -- eventually a scab will form and a scab has two components -- well, it has lots of components but it has two main components: one of them is red blood cells and the other is this molecule called fibrin. Fibrin has a precursor molecule which circulates in the blood all

the time and when it leaves the blood and leaves blood vessels when the blood vessels are damaged due to tissue injury, in this case fracture, the fibrin starts to form and it forms a meshwork that binds the red blood cells together and that's what we recognise as a scab eventually.

Down the microscope you can't recognise the very earliest stages of fibrin formation. The fibrin, as its name would suggest, is a fibular protein, it's long strands of protein and the fibrin is -- forms in these strands and then the strands bind together, they get thicker and it is only once they reach a certain size that you can start to see them down the microscope and --

Q. So if you're bleeding in life how long is it before the fibrin starts to be something that you can see? Obviously under a microscope but~...

A. Yes, so it's first seen at around about six hours. It is usually visible by 12 hours and it's very, very obvious at 24 hours.

Q. So if you were asked to look for and found fibrin, does that help you identify the timing of when the bleeding started?

A. Yes, and in this particular case I felt that it indicated that the fractures had -- the fracture that

led to haemorrhage, if there were haemorrhage there, had occurred less than six hours before death. But I hadn't any proof that there wasn't fibrin present and that was one of the special stains that I asked for.

Q. So this special stain would allow you to start to narrow down the timing of the fracture?

A. Yes, and also to recognise whether haemorrhage was present or not, yes. And --

Q. Because you have told us earlier the Perls stain didn't -- was negative --

A. Yes.

Q. -- for iron, which means negative for red blood?

A. Yes. And finally -- the processes that I have described so far all originate within the blood, so the haemorrhage, this is red blood cells coming out of the blood, the fibrin is a molecule that comes out of the blood and these are -- the formation of fibrin is a chemical reaction that occurs in tissue where there's been haemorrhage.

Eventually the bone will start to heal itself and you can recognise that even in decomposed bone because you saw in the images that I have shown that the bone is this pink colour and the bone itself hasn't changed as a consequence of decomposition and the bone healing also starts to form a bony like tissue and then proper bone

and that would be not completely immune from decomposition but largely immune from decomposition, so if we had said that we know what time that would have started and so we've got now a distant time from death when that haemorrhage could not have been -- sorry, the fracture could not have been older than a certain time because there was no bone healing.

Q. And if you were alive and fractured a bone, how long would it take for your body and the bone to actually start that process of healing so that you could see it if you were looking at it with a microscope?

A. Excuse me, sorry. The very, very earliest changes occur around about 24-36 hours after a fracture has occurred. By the time you start to see something that looks like bone you're looking at -- there's a sort of precursor to the bone that you can detect. By the time you're looking at bone you're looking at 48-72 hours, something along those lines.

Q. So if a fracture had occurred 46-72 hours before someone passed away, you would be able to see changes under the microscope --

A. Yes, even if the tissue --

Q. -- of bone healing?

A. Yes, even if the tissue was decomposed.

Q. Even if it is decomposed, that's something you can

identify?
A. Yes.
Q. And that wasn't the case here and you have put a red cross next to it?
A. Yes, and I can be sure of that but the yellow question marks -- or orangey question marks -- are really, those are the questions I needed to ask of the pathologist who had originally taken the samples.
Q. So in terms of the process you followed you were able to rule out certain things, ie the bone healing marked by the red cross?
A. Mm-hm.
Q. Other things you had question marks about and you wanted further information --
A. Yes.
Q. -- before you were able to rule those out?
A. Yes.
Q. Or rule them in?
A. Yes.
Q. And those included all these items which had the yellow question marks on this slide?
A. That's correct, yes.
Q. So the presence of fibrin and the bleeding, the haemorrhage and the amount or distribution of that haemorrhage or bleeding?

A. Yes.
Q. You wanted to ask about the decomposition?
A. Yes.
Q. And then one of the things that you did see -- and you've got a green tick next to it -- is the osteocyte necrosis.
A. Yes, and that was -- and that was the one thing that I saw which indicated that this fracture had occurred in life.
Q. And that can only happen if you are alive when the fracture occurs?
A. Yes.
Q. So as soon as you saw that you were able -- you had an initial indication at least that this is something that had happened when he was alive?
A. Yes, but I needed more evidence and that was looking for the bleeding.
Q. Right, and at that stage you have said there more than two hours before death, is that when the osteocyte necrosis can start to be visible to you?
A. At the time that was --
Q. Sorry, yes, in 2017.
A. Yes, in 2017, with the knowledge that I had then, which was both my own knowledge and understanding but also information that I had been given as part of my -- the

request for me to do the work, I believe that the fact that I could see osteocyte necrosis and that Mr Bayoh was an adult meant that the process had occurred more than two hours before his death.

Q. Thank you. Now, I know that we will be coming on later on to the developments that have taken place since 2017, so we will come back to that, but we're now -- I think we have an understanding of the questions you had in your own mind and we're going to move on now to the next slide and to talk about what happened after you had determined these questions, but I'm conscious of the time and I wonder --

LORD BRACADALE: Would this be a convenient point to take the break then?

MS GRAHAME: Thank you.

LORD BRACADALE: 20-minute break.

(11.27 am)

(Short Break)

(11.55 am)

LORD BRACADALE: Ms Grahame.

MS GRAHAME: Thank you. Just prior to the break we had heard from you about the questions that you had in your mind that you wanted more information about, so let's look at slide 11, which is the next slide, and here you talk about the sort of subsequent events -- here we are,

"Subsequent studies in 2017", and you have identified the questions here:

"Why [was] decomposition present?

"Components of haemorrhage?"

And you have talked about:

"Haemorrhage present - red blood cells.

"Fibrin allows aging - visible >6 hours old."

Can you just summarise what we see on this slide?

A. Yes, so really this was setting up the ways in which I was going to look for haemorrhage and in the sense of looking for red blood cells and also for looking at how I might see fibrin and in order to see those two structures I needed to do some special stains where the -- which would identify, even in decomposed tissue, whether these were present or not. And the special -- the stains that we have seen so far have been pink and white and with some blue, but now we're going into other different colours of stains which are, as I explained, sort of visual chemistry, colour chemistry, and they were designed to pick out these individual components, particularly the red blood cells, particularly the fibrin, if it was present, but then also to exclude some of the other things that I mentioned that could have given this appearance inside the fracture gap.

Q. Am I right in saying that this is an area, with these

special stains, where really you are embarking on something that you have experience in but not every pathologist would have experience in at all?

A. Yes. These are particularly used in specialist bone and joint pathology, particularly bone pathology, and the reason that they are so few bone pathologists is the need for bone pathologists isn't particularly great, so we would -- we work in a centre where material is sent in to us, whether that's diagnostic material, whether it's medicolegal type of material, or whatever, so there will be no reason why other pathologists would have the level of experience that you need to be able to interpret these stains.

Q. And is it the case that other pathologists maybe have never worked with these special stains and don't have any experience of analysing the results?

A. Yes, particularly in this setting, yes.

Q. So let's move on to slide 12 please and the first question you have here is why was decomposition present. Tell us what happened in relation to that issue.

A. So I sent an email saying, you know, why was there decomposition present and what had happened that led to the retrieval of this particular piece of tissue from the fracture. The whole area of identifying fractures is very, very difficult, particularly unusual fractures

in unusual settings and even very experienced radiologists had not identified on x-rays the -- it transpired -- had [sic] identified the fracture, nor at post mortem examination had the pathologist recognised the fracture. It's in a peculiar place and, as we have seen, although my images are very large, they're highly magnified images. The break itself was small and had this sort of diagonal appearance to it which tends to hide it.

So --

Q. We have heard evidence from Dr Shearer that she didn't see it initially at the post mortem.

A. Yes.

Q. And she said it's very rare to have a fracture in the first rib?

A. Very rare indeed and for it to be restricted to the first rib, an isolated first rib, is extraordinarily rare.

Q. Thank you. So that's what you mean when you say an unusual fracture in an unusual setting?

A. Yes.

Q. Thank you.

A. And this was something that I felt was -- I mean showed the sort of character of the doctors who were responsible for looking at these tests and things, is

that the radiologists went back and did a further set of studies using I think CT scanning, which is just -- for instance it was the way in which we discovered the fractures in that mummy that I showed you, they hadn't been seen on x-ray, it has that level of sensitivity, and there they noticed an isolated first rib fracture.

They thought it was affecting just one of the two cortices but as you can see the fracture didn't. But because it's on a diagonal like that it would appear only on one side even though it wasn't. And immediately that triggered the pathologist, Dr Shearer, to go back and look at that site again and there she identified a small amount of haemorrhage and knowing from the radiology where that -- where the radiologists -- the x-ray doctors had thought that the fracture was, she then removed that piece of bone.

That was 25 days after the first post mortem examination and local tissue decomposition had started in that time and that's not unusual because the bodies are kept refrigerated rather than frozen and this was very local. It wouldn't have been noticed on the outside of Mr Bayoh's body, but it was that delay that caused the tissue to have decomposed in that time.

Q. So we heard from Dr Shearer that the post mortem was carried out on 4 May. He died on the 3rd, so the

post mortem was the 4th. There was an initial x-ray or skeletal survey on 13 May. There was no sign of the fracture. There was another x-ray done on 27 May, a CT scan on the 28th and she went back in to view it herself on 29 May.

A. Yes. You can see from the proximity of all of those actions just how careful the doctors had been and how it triggered a need to do something immediately.

Q. Thank you. So the 25-day period, was that the period during which that some process of decomposition had begun?

A. Yes, even in the -- in a refrigerated body that would occur.

Q. Dr Shearer had explained that refrigeration can slow down that process but it can't stop it completely.

A. That's correct, yes.

Q. And she explained that they don't normally freeze bodies.

A. Yes.

Q. Thank you. So you were given an explanation as to the decomposition and then let's move on to the next slide, which is 13, and the next questions you had here were.

"Nature of any haemorrhage?"

Talk us through this slide.

A. Okay. This is really just an extension of a part of one

of the previous slides that I showed you, but these are the questions that I was asking myself so we have -- if there's going to be haemorrhage there, there should be red blood cells. There wasn't red blood cells because of the decomposition process so it may be that there were never red blood cells, or that there were red blood cells that had broken down.

I wanted to see how far any red blood cells that might have been involved in haemorrhage had travelled and for that I needed to know something about the amount of blood and the amount -- and the distribution of the blood.

The importance of that is that it is possible following death for bones to bleed if they're fractured. It doesn't do very much and it only occurs for a few hours after death, but you can sometimes get post mortem fractures that are associated with a small amount of haemorrhage.

The pressure inside the blood stream is phenomenal and if during life a bone breaks then blood will be forced out under tremendous pressure, enough to burst through into the bone marrow, but particularly to burst outside the bone of a fracture into the soft tissues around that. There's some very dense soft tissues that are on the outside of a bone but an in-life fracture can

lead to haemorrhage that passes through that and into the surrounding tissue. So that's -- I wanted to know how much blood there was there and was its distribution such as to suggest that this was an ante mortem haemorrhage, so where did it go.

I also wanted to find out if there was fibrin. I didn't see any fibrin and it has a slightly characteristic morphology, so I wanted to know if there was any fibrin at all and there are fortunately some excellent special stains that allow you to look at that.

Then I wanted to know what the rest of the material in that fracture line was and I showed you those sort of streaky appearances. That could have been tissue that had been introduced from outside. At the time of fracture, or at the time of post mortem, whatever, you can get little bits of tissue that are forced in, and of course although it looks large on my slides that I have shown you, this is a tiny thin fracture with material in it.

So really I did those stains to make sure that what I -- I did the stains to look for the debris in the fracture line to make sure that I could exclude it being from somewhere else. And then, as I say, there are fungi that are part of the decomposition process and they are filamentous, they have long arms that come out

from a rounded body, and I wanted to make sure that some of the things I was looking at weren't fungi because they can disturb the picture greatly and you can -- you know, they mimic a lot of different things.

Q. I would like to look in the next slide, 14, which shows the tissue stain that you -- tissue that you were talking about earlier and this is a larger image of one that we saw in the earlier slide and you say here, "Sent images of fractures site". Can you talk us through this please?

A. Yes. Can I just first draw your attention to outside the circle, particularly at sort of -- what are we looking at -- 11 o'clock. You can see some little white dots overlying the pink. Could I --

Q. Could you touch the screen there and highlight those for us?

A. In that area. These are bubbles and these are bubbles in the soft tissue and they are gas bubbles. I showed you the effects that the gas can have on bone marrow, but in soft tissues like the ones that you find around bone, bits of fat and so on, you get these little bubbles, so there's evidence here of decomposition and when you start to look, you can see more and more and more of these bubbles.

But the bit in the circular area, to the left and to

the right of the circle are bits of bone, they're the two parts of the rib, and Dr Shearer would have taken this sample in order to have the fracture at the centre of the sample. And also at the centre of the sample you can see this dark red colour. I felt that that was sufficient evidence of haemorrhage to be worth pursuing and that -- could I have a line? Thank you. That red line marks the edge of the bone and you can see that the -- there will be one above that as well, but it's this one I'm looking at and you can see that the haemorrhage, or that dark red area extends beyond the edge of the bone which would be one of the things I would want to look at in more detail to see if there had been haemorrhage during life. As I said, you need to have pressure and the pressure forces the blood out.

Q. So the dark red area seems to have extended beyond where the bone is?

A. Yes.

Q. And that could be because of the pressure during life of the blood --

A. Yes.

Q. -- moving away from the area?

A. Yes, and I don't think you would have seen that had the fracture occurred after death.

Q. So if it had been a fracture after death, or

post mortem, you may not have seen that dark red area --
A. No, no.
Q. -- to that extent?
A. No, you almost certainly wouldn't.
Q. And you were talking about red blood cells and do they break down as part of the process of decomposition you said?
A. Yes. I think it's the next image. Could I --
Q. But while you look at that, it looks darker, it looks darker there, and does that mean that the cells are still there, or is that just some sort of residue?
A. No, the red of red blood cells comes from the haemoglobin and the haemoglobin is contained within the red blood cells. But if the red blood cells burst, which is what happens in decomposition, then the red colour will remain for some time because you have got the release of the haemoglobin. You can see it when it is inside the red blood cells but you can also see it when it comes out of the red blood cells.
Q. So this could be red from inside cells but the cells themselves maybe are not --
A. Wouldn't be visible, yes.
Q. Right, thank you, sorry. At the bottom you said:
"Area circled: Dark red, supporting possible ante mortem haemorrhage."

A. Yes.
Q. So that's what you were thinking at that time?
A. It was, yes. I was sent several images. This is the one that showed that feature best.
Q. Can we move on to the next slide please. So I think this is slide 15 and you talk about red blood cells here. Tell us what we can see.
A. So if we look at the left-hand picture, and wherever I have used images that aren't my own you will find a little description of where the image has come from. So the left-hand picture is a picture of red blood cells. It is in black and white so they don't appear red, but they look like little doughnuts and they are and they're really balloons, they don't -- unlike other cells they don't have a nucleus, they're not alive in that sense, so they're little balloons that are filled with haemoglobin and like balloons they have an outer surface to them which -- so if you think about a balloon, the thing that you get in the shop is just the surface and you fill it with air. That's the same with the red blood cells except they're filled with haemoglobin and when they burst, although you can't -- as part of decomposition -- although you can't recognise them because you can't see their shape because that shape doesn't exist any more, the surface is left behind

and that's really important because red blood cells, unlike all other cells, have this molecule which I have written down here as Glycophorin A or GlyA, so when the balloon bursts there are still fragments -- we have all burst balloons and there are little bits of balloon skin on the floor, so that's what this is like, so you can't see the cell -- the balloon -- but you do leave behind these little bits of the surface and the surface contains this molecule, Glycophorin A.

Q. So you can identify that from testing, can you?

A. Yes, and the test that we do is called immunohistochemistry but that's a bit of a mouthful so we always call it IHC. And IHC is a way of specifically recognising a molecule within a tissue and in this case it's Glycophorin A, so this will only detect Glycophorin A, it can't detect anything else, and the way in which we visualise that so we can see it down the microscope is by a brown stain, so wherever there is Glycophorin A in immunohistochemistry, then there will be a brown stain.

Q. And that's what we see in the middle image?

A. Yes, the middle image is slightly different from the right-hand image. The -- which is the image which we have seen before, with two of the three pieces of bone on.

Q. That was the H&E stain?
A. That's the H&E stains, yes. The left-hand one is very similar to the left-hand picture in the left-hand part of the middle, but the -- because it's a three-dimensional structure and you're going down further and further down into the loaf of bread, the image that the -- the shape will change and the right-hand image has changed and I will explain that in just a moment.

We have focused up to now on really the left-hand image and you can see that in the brown and white stain the line of the fracture, which was a green line that I put in, and that runs from -- can I have a line? Thank you. And that runs down through there.

Q. That's the diagonal fracture you were talking about?
A. Yes, yes. Dr Shearer's laboratory had put more than one piece of bone into the tissue block and that's why we have these three different pink bits and as we have gone down through the tissue the piece on the right has changed because we have gone -- we're looking at another area of a three-dimensional object and -- have I still got a line? Thank you.

Now we can see the same fracture line but because it has been turned over it runs in the opposite direction, which is now the fracture that can clearly be seen in

the -- can I have a circle?

Q. So is this a different perspective but of the same fracture?

A. Of the same thing, yes. So the bone was like this (indicates), it was cut into two halves and the two halves placed down on to the thing. But they stuck up and we have gradually been cutting up through them.

And this area, which just looks like ordinary soft tissue, has now become the area to the -- above line 2 and it quite clearly has got bone and bone marrow in it, so we're now seeing properly down into that fracture on both of them; same fracture, different areas of the same fracture. And I think the brown stain is obvious.

Q. And the brown stain that we see contains the residue of burst red blood cells?

A. Blood cells, yes.

Q. So are all the brown areas in the middle image those residue parts of the -- the balloon skin of the red blood cells?

A. Yes, they are, and red blood cells are made in bone marrow so you would expect something in the bone marrow as well and if you look on the right-hand image -- the bone marrow has been lost from the left-hand image as we have cut down through it, but in the right-hand image more bone marrow has appeared and

there's a relatively normal appearance above line 2 -- again can I have a circle? Thank you.

So that's what bone marrow would normally look like, there's a little bit of brown in there. But when we look at the area that the yellow arrow is pointing at, we can see rather more brown material than we would have expected, but of most importance is the area indicated by the red arrow, my original red arrow, where you can see brown that's extending out beyond the edges of the bone.

Down the microscope it is easy to see the edges of the bone tissue, but the photograph makes that rather more difficult, so I have drawn around the edges -- the outer edges of the bone and you can see the area that the red arrow is pointing to and above that is some distance outside the red -- the edges of the bone.

Q. So on the -- where we see the number 1 on the middle image we can see a lot of brown there.

A. Yes.

Q. And then that appears to extend beyond this black line that's been drawn?

A. That's correct, yes.

Q. Am I right in understanding the black line is where the bone is seen, or was seen by you?

A. Yes, that's the edge of the piece of bone itself.

Q. From this slide?
A. Yes.
Q. And, as you say, the brown stain extends beyond that black line.
A. Yes.
Q. And what did that mean to you?
A. Well, that meant -- first of all, the brown staining and the quantity of brown staining indicates that there was haemorrhage present. The fact that it goes outside the edge of the bone and bursts through this sort of fibrous, this sort of coating of the bone and into the soft tissues means that there had to be a high pressure of blood at the time that the fracture occurred and that meant that the fracture occurred in life.
Q. So this brown image is really identifying the areas of blood or haemoglobin that's come out and spread beyond that bone area?
A. Yes, it's the surfaces of the red blood cells where they were in life and then as decomposition had occurred in these areas they just left behind the sort of coverings of the balloon which is picked up by the stain (inaudible).
Q. And if that fracture had occurred after death, would you expect to see so much brown staining beyond the --
A. No.

Q. -- this -- the bone?
A. No.
Q. Thank you. Let's move on then to slide 16 please. We see a number of other images here.
A. Yes.
Q. And are these further stains?
A. Yes, these are further stains. It's quite a complex slide, but it breaks down into three parts which I have called MSB, EVG and PAS, and the stains on the right-hand side come from staining manuals and they show what the stain would normally stain up in a living tissue.

The most important of these is the MSB. It stands for Martius Scarlet Blue but basically visible fibrin stains an orange-red colour and collagen stains blue. Collagen is the major supportive molecule that we have in our bodies. Everything is held together with collagen and where I have -- and the left-hand pictures are the stains used in Mr Bayoh's tissues and the thing about the MSB is that fibrin comes out this really dense orange-red colour and, as you can see, there is no orange-reddy colour in the left-hand image, which is Mr Bayoh's fracture site, and there is collagen, it's a slightly different colour from the right-hand one, but I have indicated on the left-hand one where the blue

collagen stains. But interestingly in the middle, going from top right to bottom left, there's no blue colouration, there's no bright yellow colouration, so this isn't collagen that's been forced into the tissue as part of the fracturing process, so it shows that there's not fibrin present, but it also shows that the material, the debris in the gap, in the fracture gap, is not collagen.

The next picture --

Q. Can I just ask you a few questions about that.

A. Sorry, of course.

Q. So the image on the top right -- we're on the MSB staining -- that's from a textbook showing textbook examples of the results of MSB staining?

A. Yes, yes.

Q. And we can see there blue and yellow and they symbolise different things.

A. Yes.

Q. Is the image on the right an image taken from a fracture?

A. No, the image on the right is part of a placenta and there's a lot of fibrin in a placenta following delivery.

Q. So it gives you a good example of the colours that you can look for and identify.

A. Yes and --
Q. And the fibrin comes out and develops --
A. It's an orangey-red colour.
Q. -- during life, it's orange red, and that exists when you have a fracture when you're alive?
A. Yes, if you've got visible fibrin, yes, it would pick it up.
Q. Is there a timescale where the fibrin will become visible to someone looking under a microscope?
A. Yes, and the same applies to whether or not it is stained with MSB and that is that you would not expect to see it less than six hours after -- in a fracture that has occurred less than six hours before the time that the fracture is removed, which in a lot of the cases of course is the time of death.
Q. Right. So you would -- if there had been a fracture in life and it had occurred six hours prior to death, there might be the beginnings of fibrin starting?
A. Yes, yes.
Q. And that would be the very strong orange colour?
A. Yes.
Q. So on the left, which is an image taken from the slides you had available from Mr Bayoh, there's nothing of that?
A. No. The reddy colour that you can see at the top -- and

in fact it's the top left-hand corner of all three of those slides -- is bone and bone stains in a funny way, but you -- with these stains, just because it's bone, but nevertheless the stain is not outside the extent of the bony tissue itself.

Q. Right, so you were able to look at these and as a result of that MSB stain were you able to say to yourself that there was no visible fibrin, so the --

A. Yes.

Q. -- and draw a conclusion about the timing of the fracture from that?

A. Yes. I had had to prove first of all that there was haemorrhage, which we did with the Glycophorin A stain, and now I can say, "Well, there was haemorrhage in this area", but haemorrhage that occurred within a timeframe prior to death that did not allow fibrin to have formed and so probably less than six hours, certainly less than 12 hours before death.

Q. So you're starting to narrow down that window --

A. Yes.

Q. -- when the fracture could have occurred.

And then, sorry, you were about to move on to the next stain, EVG.

A. Yes. This is a very complex stain. The important thing to note is that the picture on the right is from

a ligament and a ligament has got two components to it. It is made up of very dense collagen, but because ligaments have to stretch they also contain another molecule called elastin, which does what it says on the tin really, the elastin is a stretching molecule and the elastic van Gieson picks up elastin --

Q. Is that EVG?

A. That's -- sorry, that's EVG, yes. And the elastin is this black colour and you can see these fibrils of elastic tissue and the brick red colour is collagen.

Q. So this is a different colour, but it's just because it's a different stain?

A. Yes, and this stain is used specifically because it can show these different molecules, the collagen and the elastin, with a big contrast between the two and --

Q. And this is a textbook example again on the right?

A. Yes, all the right-hand images come from textbooks and I have put those in the little boxes to indicate where they have come from.

Q. Thank you.

A. And just at the bottom right-hand corner you can make out -- of the left-hand middle image -- you can see a little area of red, which is collagen, and that corresponds in a previous section to the one above where the collagen came out a blue colour.

Q. And that's where your black arrow points, bottom right-hand side?
A. Yes, and there is no elastin in here and that's important because there are rounded structures in here and rounded structures in histopathology usually indicate blood vessels and blood vessels tend to have elastin within their walls, so the rounded structures were not blood vessels in that sense.
There are some little bits of black scattered across. They are bits of bone. As you can see, the bone also stains a sort of browny-black colour. That's the piece at the top left of the image, but you can't -- it's just the way the bone behaves, it's different from all other tissues in respect of the way it stains.
Q. So on this left-hand middle image we see the bone in the top left-hand corner and then other areas in the remaining part of the slide which are that dark brownish colour, if I can call it that?
A. Yes, that's --
Q. That's the bone?
A. That's the bone, yes.
LORD BRACADALE: Ms Grahame, the transcript seems to have stopped. I think we will rise for a few minutes to see if we can get it back because it is quite important for following this evidence, so we will rise to see if we

can resolve it. It is an issue with the real time transcript that we have so we will see if we can sort that out.

(12.29 pm)

(Short Break)

(12.37 pm)

LORD BRACADALE: The issue is not resolved but I think we will just carry on and the stenographer will pick it up later.

MS GRAHAME: Professor, we were talking about elastin and we had talked about the EVG test, you have identified on the left the areas of bone. So you had ruled out to some extent that elastin was present; what was the significance of that so far as you were concerned? This is slide 16.

A. I mean it might be possible for ligament-like tissue to be forced into that gap but the really important thing is that amongst the debris are rounded structures and rounded structures are often blood vessels and blood vessels would contain elastin within their walls.

That isn't completely true for bone marrow because there are rounded structures that are blood vessels that don't contain elastin but some of the other stains -- and we will see one in a moment -- show that they weren't those.

Q. Right. So it wasn't inconsistent in any event with your views, as they were developing, that this happened ante mortem, pre-death?

A. Yes.

Q. Thank you. And let's look at the PAS stain at the bottom of the page.

A. This is another one of those really bright stains for picking up particular molecules and the surface of fungi is covered in sugar and this picks up sugars and they stain that purple-magenta colour, and you can see the filaments that I was talking about. This again is not a fracture site, this is just a control tissue that we know contains fungi and then we know that where those purple -- if you just follow the right-hand arrow up, you can see a little strip of a bright purple material and there's two or three to the right of it, some to the left, some down the bottom just above my name.

And when you look across to the other side, to Mr Bayoh's fracture site, there is no evidence of fungi in there and the fungi -- because they're part of the process of decomposition -- would not have decomposed and so they would -- sorry, the process causing decomposition, they would not have decomposed and so the fact that there's no staining there means that a lot of those sort of streaky looking colour changes that I have

shown are not fungi.

Q. And the fact that we don't see fungi in the slide in the bottom left, what was the significance of that to you?

A. Just simply because I wanted to exclude the sort of stripey material that was there being fungi, so if it's not fungi it has to be something else. We have -- we know it's not collagen, we know it's not fibrin, so it must be some part of the clotting process that has undergone decomposition, or at least that's how I interpreted it.

Q. Thank you. Then let's move on to the next slide which is 17 and I think this is where you sum up what your view of the fracture was in 2017, when you did your report for Crown Office at the time.

A. Yes.

Q. Can you explain to us what your view at that stage was?

A. Yes, this was a solitary left first rib fracture and the fact that it is a solitary first rib fracture has significance as to the cause.

From the fact that I could see extensive bleeding using the Glycophorin A stain, both within the fracture gap and outside in the soft tissues, and the presence of osteocyte necrosis which occurs in life means that the fracture occurred in life.

Because of the osteocyte necrosis, the earliest

I had ever seen that in an adult was two hours and that's been the experience of the few colleagues that I have who look in this area and that there was no visible fibrin, which should start to be seen at six hours, my conclusion was that the fracture probably occurred between two and six hours before death.

Q. Right. And you said in relation to the fact it was a solitary first rib fracture that that was of significance.

A. Yes.

Q. Can you explain why you said that?

A. Yes. I have shown you a diagram of the relationships, that's other structures, surrounding the first rib and although first rib fractures themselves are rare, when they occur they tend to occur in association with fractures of either other ribs, or of the collar bone, or of other structures in that area, so if there's just a solitary first rib fracture it limits the ways in which that fracture could have occurred.

Q. Thank you and we will come on to that.

A. Yes.

Q. So this was your view in 2017 when you prepared your report --

A. Yes.

Q. -- for Crown Office. Let's move on please to the next

slide, 18. You move on here to talk about the cause of an isolated first rib fracture generally and in this case. Then if we can move on to 19, I think you have reinserted the images to refresh our memory about the location of the first rib --

A. Yes.

Q. -- in relation to the other structures in that area.

A. Yes.

Q. Then if we can move on to 20 please. This slide is headed:

"Causes of isolated 1st rib fracture (either side)."

I'm interested -- you were asked to consider the mechanism and the causes, potentially, of this fracture and I would like you to take us through what you have looked at in this slide.

A. Okay.

Q. So this is --

A. The image on the left, or the image is that of a first rib. You can see that it's a flat bone and at the top -- can I have a circle? Thank you. These -- the two circles that I have drawn are where the bone has joints with the spine bones, with the vertebral bodies and the wing of the bone, so this is at the spine end and there are two joints.

Q. So the top of this image is at the back, someone's back

area?

A. Yes, yes.

Q. And the bottom of this image is towards the front, to the sternum area?

A. Yes, and we've got this sort of slightly irregular edge to the left-hand bottom which is where it joined on to cartilage that breached the gap between it and the breast bone.

Q. The sternum?

A. The sternum, yes.

Q. So this is an image in the position that if you were looking at someone face on, their first left rib would be like this in this position; is that right?

A. You would be looking at them from the front and above.

Q. Oh, this would be above it. Yes, sorry.

A. That's okay, and the -- when I first drew this image the yellow lightning thing was where I believed the fracture was from the description that I had seen. I'm not a radiologist and -- but the radiology was very specific about the site where the fracture was and this turns out to be important and I believe it is actually the site as well now. Dr Shearer confirmed that, didn't she?

Q. Yes, well, we -- when you raised this we went back to Dr Sheerer and we took her evidence last week and asked her to look at this image and she said this was -- we

explained it was an indicative image and she said that that was correct.

A. Okay, thank you. There's a technical term on the -- on that image as well and it says "scalene tubercule", that's a slightly raised area on the bone and it's sort of hatched in under the green, if you can see that. This is important when we come to the last of the indirect trauma elements that I've got and I will return to that, if I may.

Q. Yes, thank you.

A. So there are very, very, very few people in the world who will have significant experience of isolated first rib fractures and I am not one of those. So I have seen first rib fractures, I have seen first rib fractures linked with other fractures of other bones. I may -- I can't remember whether I have actually seen any isolated first rib fractures, so in order to produce this list I went to the medical literature and I had to go right back to the 1950s in order then to gather sufficient cases and descriptions of where these fractures occurred.

Q. And is that an indication, Professor, of the rarity --

A. Yes.

Q. -- of an isolated first rib fracture?

A. Yes, yes, very, very rare indeed.

Q. Thank you.

A. But there are doctors who take an interest in certain things like this and they will contact their colleagues and they will get information and then they will pull that all together and publish it in the medical press, so I went to the medical press to get these potential causes of an isolated first rib fracture.

So there is direct external trauma, and I have discussed that when I was talking about the triangular bowl-shaped thing, a small foot kicking directly onto that rib, that sort of size and we can judge the sort of size just by feeling on ourselves how big that triangular area is. And that would cause a fracture in the site that I have indicated on the image.

This area of the body is full of links between different bones and there are muscles, there are tendons, there are ligaments and one of the more common causes of this very rare fracture is falling onto an outstretched arm and here the forces are transmitted along the arm, up into the shoulder and then transmitted through all these ancillary structures to the first rib and can cause it to fracture. And it will only affect that rib because of the way that rib is attached to all these ancillary structures around it.

A blow to the shoulder can also transmit energy in

the same way as a fall on to the arm. It would though cause quite marked soft tissue injuries: bruising, some sort of marks that might have come from the cause.

Then finally there's this fracture caused by violent muscular contraction. That means that someone who contracts their muscles very, very hard -- and the examples tend to come from people who are habitually lifting heavy loads and putting them on to their shoulders, examples are farmers who can carry a bale of hay on both arms, or coal miners -- and as I said the literature goes back a long way. And one of the most interesting things about these, and important from our perspective, is that they tend to occur in that green area that I have marked on the image of the rib.

So when I went through and analysed all the cases that I could find, they all appeared to occur in that area, so if the fracture is away from that area then it is unlikely to be caused by violent muscular contraction.

Q. So this slide essentially identifies potential causes of this rare type of fracture and it is from -- and you have specifically gone to the medical literature --

A. Yes.

Q. -- to research all the potential causes --

A. Yes.

Q. -- that have been identified by other doctors --
A. And published, yes.
Q. And published. And so one can be direct external trauma?
A. Yes.
Q. And then indirect trauma from falling on an outstretched arm; a blow to the shoulder, say if you fell or you were struck with something?
A. Yes.
Q. Although that would be -- ancillary to that you may have damage to other structures like the skin or muscle or bruising or something along those lines?
A. Yes. When you fall on an outstretched arm my personal experience is that you don't show the same level of damage to your hand as if someone had applied a hard force on to your -- directly on to the soft tissues of your shoulder.
Q. Thank you. Then the fracture caused by violent muscular contraction, I'm interested in the type of circumstances that could give rise to this violent muscular contraction.
A. Well, as I say, one of them is lifting heavy loads and most of the cases were in people who habitually lifted heavy loads, it was part of their job basically. They were by and large men who were doing heavy manual tasks.

There are one or two descriptions of someone who wasn't used to lifting a heavy weight -- there's one of a guy who lifted a mattress and a few days later started to notice pain and that was shown to be -- to have -- the pain was coming from a fracture of this rib.

Q. There's obviously different methods or manoeuvres or techniques for lifting heavy weights. In your review of the literature was there any commonality between any of the --

A. There was nothing specific, except that by and large they were people lifting weights up.

Q. In front of them with --

A. Well, the literature wasn't that specific.

Q. Right.

A. Yes.

Q. But you have said that that's normally in this green area that we see in the image?

A. These fractures, yes.

Q. When you researched that as a possible cause, was there any indication of how common that is? Obviously in the context of first rib fractures being very rare.

A. Yes, of the number I saw -- that I reviewed I think we were looking at something like 10% to 15% of the fractures of the first rib that were caused by this type of accident.

Q. Can you explain from your reading when it says, "Violent muscular contraction", is that some sort of spasm or is it just some sort of overexertion of the muscle?
A. It's usually overexertion. There were one or two cases I think where it was due to a spasm, but by and large these were lifting heavy weights.
Q. Then looking at the image again, could you help the Chair understand -- we saw in your earlier image that the first rib goes underneath the clavicle. Where would the clavicle be positioned in relation to this image?
A. It would go from the bottom left upwards towards the right middle -- can I have a line?
Q. Could you have a line?
A. It would run in -- and can I keep the line? Sorry. Can I have another one. I'm not winning, sorry. No, I wanted to have two parallel to one another. Yes, super, thank you. In that sort of position. The scalene tubercule has got two little dinges either side of it where the blood vessels pass through going towards the neck and that happens underneath the clavicle.
Q. So the scalene tubercule is underneath where the clavicle would be?
A. Yes, yes.
Q. But the lightning bolt yellow zigzag line is towards the back of the person?

A. Yes, and quite a long way back.
Q. Right, so not under or just beside the clavicle?
A. No.
Q. Thank you. Could we move on to the next slide please, which is 21. Here I think you say:

"Based on witness statements available at the time, my knowledge and understanding ..."

And then you set out what your findings were. Does this relate to your findings generally, or just in 2017, or have you remained of the same view since 2017?
A. This particular slide refers to my view in 2017, but I have -- it is my belief that these are still pertinent now.
Q. Thank you. Let's go through these. You have four bullet points here and I see that you have -- the top and the bottom say "Unlikely" in red next to them?
A. Mm-hm.
Q. And then you have one that's green and it says "Likely" and then one that is a browny colour "Possible"?
A. Yes.
Q. Can we look first of all at the ones you have classified as "Unlikely".
A. Okay. Although direct external trauma can cause an isolated first rib fracture, it's uncommon because of the way in which the rib is protected, and we have

discussed this protected area. So it's an isolated fracture, therefore I felt that was unlikely -- not impossible, but also there was no reported event of direct trauma of a type that I felt could have caused this by directly applying force of sufficient amount into the bottom of that little bowl that I showed, the triangular bowl.

Q. So you drew a triangle on the image and you have the bowl and it would have to be a fracture in the base of that bowl, I think you said?

A. Yes. As I say, it's well protected by the muscle at the back, supported by the shoulder blade and the clavicle at the front and if there was sufficient force to go through those -- past those structures, then they would have been damaged. So it would need to have been a force that went directly downwards on to the middle of the bowl and I -- at the time there was no evidence that that had occurred.

Q. So nothing that you could see in the statements that you were sent?

A. Yes, that's correct.

Q. If there was direct external trauma, what would you expect to find, or would you expect to exist externally on the skin or in the muscles or anything?

A. Yes, so again this is outside my experience and probably

outside most people's experience, isolated first rib fractures caused like this, but you would imagine that there would be bruising -- this is quite loose tissue so there would be swelling as well, as a consequence of a direct blow in that area.

Q. We have heard from Dr Shearer who did the post mortem on 4 May that there was no external damage to the skin, to the tissue, to the muscles or -- no bruising, that type of thing, but would you have expected something along those lines to be visible?

A. I would have thought so, even if it wasn't on the skin you would have expected to have seen something on the soft tissues below the skin.

Q. And is it significant that there is only the isolated first rib fracture in that area?

A. Yes, because a lot of other causes -- in particular trauma -- would have -- I believe would have been reflected in fractures of other bones, of damage to soft tissue and so on.

Q. Right, I'm conscious of the time but we have heard some evidence that there was baton strikes to the left-hand side of Mr Bayoh. Would it -- would a direct external trauma possibly include a baton strike?

A. I'm no expert on police batons so I don't know how heavy they are. I suppose that would be on the blow to the

shoulder equivalent. I can't see how a long stick-like structure put on to -- across here would have caused that fracture without causing damage to any other tissues.

MS GRAHAME: Thank you. I'm conscious of the time.

LORD BRACADALE: Shall we stop for lunch then and sit at 2 o'clock.

(1.00 pm)

(The luncheon adjournment)

(2.02 pm)

LORD BRACADALE: Ms Grahame.

MS GRAHAME: Thank you, we were on slide 21 just before lunch and we will go back to that. We were talking about -- you had indicated direct external trauma was unlikely. One of the things that you mentioned was, "No reported event", we can see that in the blue on there.

Would you agree -- we asked Dr Shearer about this last week. Would you agree that in relation to your comments and your findings that when the Chair is coming to consider all of these matters he shouldn't simply look at your evidence in isolation, but the actual evidence he has heard during the hearings about the events at Hayfield Road are an important part of the consideration?

A. Yes, absolutely. And remember this was in 2017 that --

I wasn't told of any reported events but clearly I'm working on what I have been told which may not necessarily correspond directly to the evidence that's been heard here.

Q. We have heard considerable evidence in this Public Inquiry which may have enhanced and added to evidence that was available in statements and the Chair should consider that as well?

A. Oh, absolutely, yes, of course, yes.

Q. Thank you. Let's move on to the -- I said we would look at the "Unlikely", the red sections first. We see at the bottom it says, "Violent muscular contraction", and we discussed that earlier today?

A. Yes.

Q. And you have given some examples there below:

"Press-up + heavy weight on body: fracture site inconsistent."

Can you talk us through why you categorise this option as unlikely?

A. Yes, what I have tried to do here is relate the site of the fracture to what's known about the causes and whether they have any specific site and the fractures that were under that little green area on the picture of the first rib are the ones which are due to this thing I called violent muscular contraction. So I'm really

basing that as being unlikely on the site and the site is more specific in these cases, if I have understood what I have read, because the bone is a bit thinner there where -- that thing called the scalene tubercule, either side of it, the bone is thinner and therefore is a preferred site of fracture, when you're putting all the forces around violent muscular exercise together. And I have put down here:

"Press up + heavy weight on the body~..."

And of course that would constitute violent exercise, violent muscular contraction in this sense.

Q. Just to touch on that, we have heard evidence in the various hearings we have had about a press-up taking place during the course of the restraint at Hayfield Road and obviously that will be a matter for the Chair, but a number of witnesses described a situation -- I will give you some of the evidence that one of the witnesses has commented on, a Nicole Short, who was watching this from a distance:

"I'm positive he was kind -- he was in a kind of press-up position and that's how he was gaining kind of -- he was -- as though he was trying to get up off the ground and I just remember thinking those are three -- three of the biggest guys on the shift and he is managing to lift them up."

And another officer, PC Tomlinson, in June of last year described him being in a press-up style position and using that position to lift himself up off the ground whilst attempts were being made to restrain him by PC Walker and PC Tomlinson. And then another officer described him being face down, head off the ground, trying to force himself up using his arms like a press-up?

A. Yes.

Q. So does anything I have said there about the nature of that press-up, or the way that was being described by the witnesses, alter your view that that would not be the type of violent muscular contraction that would --

A. All I'm basing that being an unlikely cause of the fracture is the site and the site comes from my reading of the literature, so I haven't found any other sorts of -- any other descriptions of fractures describing in any other areas on the first rib as a consequence of lifting, but as I say most of those were people habitually lifting things, not pressing up. So within the circumstances as I found them I felt that that was unlikely or less likely than some of the other causes, but that would certainly constitute violent muscular contraction.

Q. But not of the type that you were reading about in the

literature?

A. Not of the type -- and causing a fracture in a site that's different from what the literature says.

Q. Then where you talk about heavy weight on the body, we heard that one of the officers was 6-foot 4 and 25 stone and the Chair has heard different evidence from different witnesses about the nature of the restraint and what was happening, but some of the evidence that he heard related to -- and this was from a PC Good -- PC Walker, the 25-stone officer:

"... lying across the top of the man's back towards the upper half in an effort to stop him from forcing himself to his feet. This was effectively to assist in pushing him to the ground."

So that sort of description of a weight or being -- a person of that weight being across the upper part of Mr Bayoh's body, would that cause you to alter your view that this possible cause is unlikely?

A. As I say, I think that is certainly the sort of weight that would require very significant muscular action to push up from the ground, so yes, as I said, the only reason that I have put this as unlikely is simply because of the site of the fracture. I don't know whether this type of pressing up could cause fractures elsewhere in the bone, I just don't know. I'm just

reporting really what I have seen in the literature and they were very specific about the site always being in that area. But could it be somewhere else? Yes, of course it could (inaudible) bone.

Q. Thank you. And then you have one situation described as "Possible", this is the brown "Possible", and you say:

"Blow to the shoulder (or equivalent)."

Can you talk us through this?

A. Yes. The description in the literature says a blow on the shoulder and by "equivalent" I meant rather than something coming into contact with -- the something coming into contact being moving, then I could imagine the same situation occurring if somebody fell down on to their shoulder, particularly again if there was a heavy weight around them, if they weren't able to move their arm out and so on, so that they were falling from a height. So that's really what I meant by "or equivalent". Again, one might expect to find bruising in the tissues but really that's -- that again is outside the area that I'm really happy about, I am really just working from my knowledge of pathology and the way that tissues behave.

Somebody like Dr Shearer would obviously have much more experience of how long it takes for bruising to appear and so on.

Q. I think the evidence from Dr Shearer indicated that there was not tissue damage or bruising or muscular damage in the area of the shoulder that would have been consistent with that.
A. Yes.
Q. So in the absence -- if we assume that that's correct, then the absence of any external signs of impact from a fall on to a shoulder, would that -- what's your view in relation to this, that the blow on the shoulder could have caused that fracture?
A. Well, again I think it then becomes less likely than I have indicated here. As I say, this was the information that was available to me at the time of 2017, so that ranking is what I thought was the most likely, but if there's no bruising at all and Dr Shearer was happy that the -- that she might have expected there to have been bruising within a couple of hours of falling on to the shoulder, then obviously that then pushes that one further down from possible.
Q. We have also heard evidence about Mr Bayoh being brought to the ground by PC Walker and that was described variously as either a shoulder charge with his left shoulder, or with a couple of other witnesses they described it as a bear hug, and one witness in particular, Nelson, said he:

"... wouldn't say it was quite a rugby tackle, it was both arms round the top half of him."

And that was more -- he described it as a bear hug. That was the description that was given.

I understand -- sorry to interrupt you, Professor, I understand we're having technical difficulties again. I wonder if the Chair wishes to -- I have just been passed a message that there are technical issues and we may require a brief adjournment.

LORD BRACADALE: Well, we will adjourn briefly. I don't know what these are but we will adjourn briefly.

(2.13 pm)

(Short Break)

(2.18 pm)

LORD BRACADALE: I understand the problem was with the broadcast system this time so that's now been resolved.

Ms Grahame.

MS GRAHAME: Thank you.

I was talking to you about some of the evidence that we have heard, really to ask if that altered your views, so we were looking at slide 21 and we were talking about the category of "Possible":

"Blow to the shoulder (or equivalent)."

We have heard some evidence in this Inquiry that Mr Bayoh was brought to the ground and it is described

as:

"Some sort of like bear hug, like wrestle thing, to basically knock Mr Bayoh off-balance and take him to the floor."

And then another witness, PC Walker, said

"Answer: So I just brought my left arm across my body and shoulder-charged him with my left shoulder, with a fair bit of force."

Taking those descriptions as they are from the witnesses, is there anything within those descriptions that would alter your views in relation to that third bullet point?

A. Yes, so as I said, a blow to the shoulder or equivalent, which would be falling on to a shoulder, if someone was brought to the ground with -- in a bear hug if you like, then the impression that I have from that is that the arms would be pinioned to the side and if that was a correct impression then if you fell down on to your shoulder you would have no way of preventing your shoulder hitting the ground. You couldn't put your arm out.

So not the bear hug itself, nor do I feel a sort of shoulder charge, which I guess wasn't shoulder to shoulder -- but we have heard that there was no bruising in the shoulder area. But I could imagine a situation

where by pinioning the arms to the side the only -- the first bit of you that hit the ground would be your shoulder. But then again one might expect to find bruising and tissue damage if that were the case.

Q. So in considering that as an option it will be important for the Chair to consider the evidence of Dr Shearer as well?

A. Yes, absolutely.

Q. Then finally, the category which you have marked as green "Likely", can you talk us through this please?

A. Yes. At the time I was told that there was a fight between Mr Bayoh and his friend. I wasn't told what would have happened during that time and similarly I imagined that with -- well, more than imagined, I knew that the police had brought Mr Bayoh to the ground and in both of those situations I could imagine an arm being pressed out and that -- and then the force being delivered up an outstretched arm.

I have put "or equivalent" because I wondered whether the same level of force might be induced by hitting somebody, so rather than falling on to an outstretched arm, your outstretched arm then hits somebody with force, particularly if they were on the ground and weren't able to move, or if they did move and you hit the ground, and with what I knew at the time

about the way in which the events had been portrayed to me, that was what I felt was the most likely and it would also explain why there didn't seem to be any bruising anywhere else.

Q. So if a person fell on to an outstretched arm, or punched a person or an object or the ground, would the force travel up the arm and potentially fracture the rib?

A. Yes.

Q. Sorry, I'm pointing to my right arm but it was actually the left.

A. Yes. That was how I saw it and why, when I looked through all the different causes, I felt that that was the most likely.

Q. And if someone again was punching the ground or an inanimate object, would -- it may be that you would expect some sort of injury to be observable on their hand of some description?

A. I think if you hit the ground with your fist with that amount of force, or even somebody else, you might get damage to the knuckles. Again, this is beyond my professional expertise but I can see that that might happen. Whereas if you hit somebody with a palm, this sort of motion (indicating), or fell on to a palm, the hands are usually quite sturdy and you could imagine

them just impacting and the force being transmitted without causing any overt damage to the hand itself.

Q. And again, the Chair will have to consider any evidence from Dr Shearer about the absence of any knuckle injuries or injures to the hand that might be consistent with a punch or --

A. Yes, I was only working from the information I had. Dr Shearer will have much more experience as well as knowledge of these things.

Q. And you were looking at all the possibilities that could have caused this type of fracture?

A. Yes, that's what I was asked to do, yes.

Q. Thank you. Can we move on to slide 22 please. Then we asked you to look at some other -- in light of the information we have now we asked you to look at some other possible or hypothesised causes, so what's the -- there are a number of "Unlikelies" marked here, categorised in that way. Let's go through those first please.

A. Okay.

Q. Let's look at handcuffs first.

A. Okay. The forces required when putting on -- no, let's start somewhere else. If we were looking at trying to translate the forces that have been described as causing these fractures into other settings, then would putting

on a pair of handcuffs give that level of force as falling on to an outstretched arm, banging your shoulder down on to the ground? I didn't think that that was likely.

Q. We have heard evidence that handcuffs were -- there was an attempt to apply handcuffs to the wrist area and we have heard some evidence of marks from Dr Shearer, but in terms of the force required to cause a fracture in the first rib, is there anything that you could read in the papers, or see in your slides, that would give an indication of that level of force?

A. I just couldn't see the forces of putting on of handcuffs being -- however forcefully they were applied -- as being the equivalent to a large man falling on to an outstretched arm.

Q. Thank you. And then sticking with the category of "Unlikely", you specifically mention press-up and we have discussed that already.

A. Yes.

Q. And --

A. And as I say, that was all based on the site of the fracture.

Q. Yes. And then you have mentioned the word "Squeeze" there. Now, before I ask you to comment on this we have some -- a written statement from a consultant, Dr Carey,

who has not yet given evidence, so if I may I will read out something that is in his statement but subject of course to the fact that we have not actually heard his specific evidence yet. He talks, like you, that the fracture is a very uncommon site. He has said:

"I have been asked to consider the method of restraint deployed by PC Walker in bringing Mr Bayoh to the ground. Two separate scenarios have been described. The first where PC Walker performed a bear hug manoeuvre whereby he wrapped his arms round Mr Bayoh's body and took him to the ground. The second scenario is PC Walker performing a shoulder charge."

I have put those both to you:

"The first scenario could have caused the rib fracture since [this is the bear hug] there is squeezing occurring which is a form of restraint. The question is whether that would be capable of causing a rib fracture as opposed to the mechanism of severe pressure being applied to the chest in a side to side fashion."

I'm interested in this concept of squeezing and I wonder what your comments are in relation to that idea, that some sort of squeezing could have caused a fracture in the first rib?

A. If I could go to the image that's on this slide.

Q. Yes. Let's go back to that.

A. It's the one that's up at the moment.
Q. Oh, sorry, I thought you meant the previous images.
A. No. This is another one of those images where there is a skin and muscle outline superimposed on to the skeleton and the red arrow marks the site of the fracture. The collar bones have a very interesting function in that they are designed to push the shoulders back and they form a brace across the shoulders. That's their primary function. So in the position in which that picture is -- and I put a purple double-headed arrow below that -- the collar bones themselves are there to prevent the shoulders coming inwards and the fracture, as we have seen, is to the rib below the collar bones, so putting your arms around the shoulders would be prevented from causing squeezing because of the two collar bones.

The normal way in which somebody would grab somebody and squeeze them is under the arms and if you look under the arms you can see that there's a lot of other ribs there and yes, that is a way in which ribs can be damaged but I couldn't envisage how an isolated first rib fracture could be caused in the absence of any fractures to any of the other ribs in that position.
Q. Thank you. So in the absence of any other fractures, either lower down -- lower down the rib cage, what

was -- does your view remain the same in relation to this squeezing manoeuvre, that that remains unlikely?

A. I think so, for those two reasons. If somebody was squeezed up around the shoulders then the forces would have passed through the clavicles and -- through the collar bones and if they were squeezed lower down then the forces would be passed through the lower rib, so a force sufficient to fracture the first rib would need to overcome the resistance of the two collar bones, or the ribs -- the lower ribs -- themselves, and if they weren't damaged I couldn't see why an isolated fracture of the first rib would occur.

Q. Thank you. The next option on the final bullet point here is CPR and I think you have also indicated that's unlikely. You come on to that in the next slide.

A. Yes.

Q. But I wonder if I could ask you a couple of other questions before we leave this slide.

A. Of course.

Q. First of all you have talked about "Fight" and you say "Possible", I don't want to lose site of that. When you say "Fight", what was this in connection with?

A. This was the group of outcomes that I alluded to of somebody hitting the ground while they were fighting, or hitting somebody who was on the ground and couldn't move

and the forces being directed up the arm. And we have covered the fact that one might expect there to be some injuries to the outsides of the hands, or alternatively some sort of -- something in the description which would fit that if say somebody was lying on the ground and they were hit in the head with sufficient force to be transmitted up to the -- up along the straighter arm, what would have happened to that person who was being hit? Was there a description of somebody, Mr Bayoh, hitting the ground because he -- at some time during a fight he might have missed the person and hit the ground? It was those sorts of things that I thought, well, it is possible but I haven't heard, and I still don't think I have heard, of either the friend having the sorts of injuries that one might expect if you were hit very hard or any description of Mr Bayoh hitting the ground.

Q. Let me give you a description that we do have available and you can tell us if that changes your view at all.

A. Yes.

Q. This comes from an Inquiry statement that we have received from Mr Bayoh's friend. For those who wish to know, it's SBPI 00071, but I won't ask for it to be put up on screen. He describes an altercation with Mr Bayoh -- this is prior to him getting to

Hayfield Road -- that:

"Sheku sucker punched me from behind. He punched me on the head. I was half in, half out the door and I stumbled after being punched. He started charging towards me. I seen him start running towards me. I started running when he picked up the washing line pole. He literally chased me all the way round the back of the house with the washing line pole, a wooden one. I thought Shek was hallucinating. He did throw the washing line pole but it missed me. He pushed me on to the floor in a neighbour's garden. I think I fell over a wall. He was on top of me. He was throwing punches into my head. I tried to protect my head. He did throw a good few punches."

That's a description that's available to the Chair to consider. Is there anything in that that would be consistent with what you have described?

A. If I understand correctly then the friend was lying on the ground and was being punched, which I think is one of the scenarios that I have sort of said could lead to the same sort of forces going up the arm. The arm would have to be straight when he was hit rather than bent in that sort of way, but yes that is something that could happen.

Q. We have no other details other than what I have given

you.

A. Sure.

Q. Then I would also like to ask you about some other evidence that we have heard about a part of events as the restraint was taking place.

We heard evidence from PC Paton about his use of a baton during part of the restraint and I would like to put a description to you for comment:

"I picked up the baton~..."

This is PC Paton:

"I picked up the baton and put it across the boy's bicep. I had the baton across the boy's bicep. I was holding both ends of the baton and I was in a push up position with my whole body weight with the pressure on the baton over the boy's bicep but he was still struggling."

He says:

"I know this is not a trained method of restraint but in the circumstances I was trying to bring him under control to assist with keeping him in control and for handcuffs to be put on him."

In terms of that description, insofar as that was given, was there anything there that would indicate to you it's possible to cause a first rib fracture?

A. I don't think so, but there's no mention of how Mr Bayoh

was counteracting that force. I just -- I just don't know from the descriptions that I have given you, from heavy lifting and so on, whether trying to push your arm out -- it sounded as if Mr Bayoh was on the ground and the baton was across his upper arm, not his shoulder but his upper arm and if he was trying to push in this direction would that be equivalent to lifting a heavy weight? I suppose it might be.

As I said, it still comes down to the site of the fracture. I haven't seen a fracture other than in the green area that I drew resulting from this sort of heavy lifting. Would it be impossible? I think I have said already that it wouldn't be impossible but it's just I haven't seen anything and described other than fractures in that -- in a different site to the fracture that Mr Bayoh suffered.

Q. So would that be in the "Unlikely" category that you --

A. I think so, yes. I mean what I'm trying to do, I think, is to paint a picture of which of the causes that we know about can cause this fracture might be the most likely and obviously I still favour falling on an outstretched arm, or the equivalent.

Q. Then we also have another version in relation to PC Paton's use of the baton:

"PC Paton had a baton and passed it through

Mr Bayoh's left arm to try to pull Mr Bayoh's left arm out from under him in order to get both hands behind Mr Bayoh's back for him to be handcuffed to the rear. Mr Bayoh's left arm was under him as he lay on his left-hand side."

I appreciate that's quite a short description, but is there anything in that description -- this comes from PC Walker -- which would give you any cause to consider this could be --

A. No, I don't think so, no.

Q. Right. Then a third version from a PC Good:

"He kind of had the baton like under, trying to rotate the arm around ... it's going under to try and rotate the arm around. It would end up between the shoulder blade and the body."

Again, a very limited description of PC Paton's use of the baton but is there anything in that at all?

A. No, I can't see anything in that.

Q. All right, thank you. So we were looking at the final bullet point, CPR, and you have described that as in the "Unlikely" category. Could we look at the next slide please and then we will talk to you about CPR.

Now, I think we said at the beginning of your evidence today that the Crown had said one of the possibilities they were interested in you considering

was that this fracture had been caused by CPR and that there may have been evidence at that stage that someone had heard a rib fracture during the course of CPR?

A. Yes.

Q. Can you describe to us what we see here?

A. Yes. In my original slide, the bottom left one in the presentation, the bottom left one was animated and it showed how by doing CPR the middle of the chest is compressed, but there was no movement in the area shown in red, which is a rough area where the -- sorry -- where the fracture was.

So if we look at the other two images, the purpose of CPR is to compress the heart in order to pump blood and as a consequence pressure is placed over the heart and the top left-hand image -- again, the red marks the site of the fracture. The image shows hands held in the correct position, so interlocked, but over the heart and you can't actually see the heart because of the position of the hands. So what the right-hand image does -- it has got quite a lot of information in it. The right-hand image with the purple circle shows roughly the area where your hands would be compressing and behind it in a sort of orange colour is the shape of the heart.

There's also some other orange lines, some of which

are dotted, but they represent the outline of the lungs, but we're really interested in the heart, which is immediately below the breast bone but slightly to the left. So that's where the pressure is exerted, though you cover -- as you can see from the top left-hand picture -- a greater area with your hands, the pressure is focused on that point, squeezing the heart in order to get blood to be pumped.

The very best CPR fractures ribs and we have to accept that because that's the way in which you're now getting the heart to be compressed and at the top of that same diagram you can see that the top number, 75%, represents the number of cases in which rib fractures occur following -- no, as a consequence of CPR.

Q. And is that where we see the green marks?

A. Right, and I'm sorry, I have only just noticed that there's actually a green bit missing as well, but the ribs that are fractured are from -- the second down to the sixth are the most common and three, four, five and six are the most commonly fractured ribs. And if you look at the way in which forces would be moving outwards from compressing the chest -- and you're having to push the breast bone down very hard in order to pump blood because you're squeezing the heart -- then you can see why that might be the case. And, as I say, there should

be a green mark over the left third rib as well, I apologise that I haven't put that in.

Q. No, not at all.

A. 5 -- sorry.

Q. Sorry, no, carry on.

A. 5% is the number of cases where the first rib is fractured in CPR and this is by combining lots and -- this is -- I did a meta analysis for this, so combining a lot of data and putting it in there.

I think it's pretty fair to say that that is always associated with fractures elsewhere in CPR. I have not been able to find any evidence of descriptions in the literature of first rib fractures alone being associated with CPR. So I would have expected there to be other fractures. I would -- if the CPR had been -- had caused fractures as a consequence of the pressure that was being exerted.

Q. So certainly possible for CPR to cause a fracture in the first rib, but --

A. Not an isolated fracture.

Q. The fact it is isolated is very significant?

A. Is really important, yes.

Q. And it's that isolation of that rib that has made you think CPR is an unlikely cause?

A. Yes, yes.

Q. So if CPR had caused fractures, and it very well could, it would be more likely to be accompanied by fractures 3 to 6 in -- ribs 3 to 6?

A. Yes.

Q. Thank you. Then can we move on to slide 24 please. You have said here:

"New data have provided new insights."

We're obviously moving on to the next section of your slides. What does this next section deal with?

A. There are certain key elements of the analyses that I performed. One of those relates to the timing of the fracture and in particular the timing -- well, two things. First of all, the timing relative to the time of death; and, secondly, the absolute timing of the fracture, and particularly there I have built a reliance on the information that I had available at the time about the aging of osteocyte necrosis. So I go on to discuss those two things and -- I mean without wanting to cause any distress, one of those will be at what time did Mr Bayoh die.

The other one is what do we now know about osteocyte necrosis and some part of what I have been able to establish has come from information that the Inquiry team have given me now that you have had an opportunity to speak to a number of different witnesses and that --

and I think on the next slide, but I have put into context why I thought that that was important.

Q. Thank you. Let's move on to the next slide which is 25.

A. Yes, this is -- the first two of these, the "Clearer timeline of events", and the "Toxicology analysis" are the information -- there's extra information that has come to me now from the Inquiry team that I didn't have at the time in 2017 and I think they were very important because I was being asked what the timing of the fractures was in relationship to interactions that Mr Bayoh had with other people and I have been assured that prior to six or so hours before his death there were -- there was nothing happened to him that could have given rise to the scenarios that I have described as being likely or possible ways of causing a fracture of the first rib.

Q. Can I give you a summary of --

A. Yes, please.

Q. -- my understanding of the timeline, just so that we can put this into context for people.

So we have heard evidence from a witness called Naomi Rhodes and she described seeing a fight between two men, Mr Bayoh and Mr Saeed, his friend, and describes that as about 6.30, quarter to 7 in the morning on 3 May 2015.

We know that the police arrived -- the first van arrived at Hayfield Road, seen on the CCTV, at roughly 7.20 in the morning. That Mr Bayoh was brought to the ground and restrained shortly after that time. By 7.25 he was unconscious but breathing still, and then at 7.29, or by 7.29 that CPR was being commenced because he was unconscious and not breathing at that stage.

The ambulance arrived at Hayfield Road at 7.33 and he was attended to by the paramedics and taken to Victoria Hospital. They continued at the hospital to endeavour to resuscitate him. They used a Thumper machine in that part of the event and -- but he was not pronounced life extinct until 09.04.

A. Yes.

Q. So that's my understanding of the sort of rough timescale that we're considering as key events. Does that accord with your understanding of --

A. Yes, there were one or two other things that I took away from the notes. The first is that I think it was a doctor called Dr Pickering who was in charge of resuscitation and there was a report -- I'm not sure if it was by one of the police officers -- of feeling a pulse on Mr Bayoh when he was in a break in the CPR.

The paramedics also reported that when they were going to shock him, the shock machine I think generates

a ECG as well, that they found electrical cardiac activity as if the heart was pumping spontaneously, and I think when Mr Bayoh arrived at the hospital there were also reports of him having a spontaneous cardiac output, which means his heart was beating, and it was -- and then there was a suggestion by the senior doctor that maybe throughout all of this period there was evidence of cardiac output, so -- and I looked at that quite carefully and I felt that that was an important observation.

While the -- all of the time that Mr Bayoh was being resuscitated, before he got to hospital, there was considerable difficulty in intubating him because his teeth were very tightly clenched together. But once he was in hospital he was seen by a proper anaesthetist and so on who was able to intubate him and during the time that he was being resuscitated using the thumping machine the anaesthetist was putting I think pure oxygen, but whatever, into his lungs and was also recording a pressure wave from a major pulse.

I can't tell you what that is, but it did mention in the notes that I saw that that pressure wave was measured at between 70 and 140 millimetres of mercury and normal cardiac output is 120 millimetres of mercury, so the -- from what I could see there was some

spontaneous cardiac heart activity at times, at least during the period between starting CPR and getting him into hospital -- and after all that's what CPR is about, it's about getting the heart to beat properly again, so that meant that it was good CPR and that the very careful way that, as I read the notes from the hospital, were that there was -- that the CPR that was carried out was successful in the sense that it was pumping blood around the body. And nowhere did I find out exactly when that stopped, but I have made an assumption that they carried on doing everything that could be done until they declared Mr Bayoh dead at 9.04.

To me that's important as someone who ages fractures because fractures are aged from the time of death and there's always a discussion about how good CPR is at extending life, if you like, by itself in terms of how much blood is being pumped around. But if again, as I say, I have read the notes correctly, then there seemed to be very good evidence that the CPR was working very well at pumping blood around the body and therefore it would be reasonable now to put the timing of death at 09.04.

Q. Thank you. And that is the point from which you will start to calculate the age of the fracture?

A. Yes, yes.

Q. Thank you. So, sorry, I interrupted you on this particular slide 25.
A. You have actually taken me to my point of the management of collapse and arrest.
Q. Right, and then you deal with toxicology analysis?
A. Yes, I have expanded on that in one of the later slides, but I was told, for instance, that in 2017 that there was -- that part of the toxicological analysis showed that alcohol was present. I know that that now is not the case and I have been racking my brains to try and remember -- and I can't and I haven't mentioned it in my report -- of what was known about the amount of the anabolic steroid nandrolone that was in the system and I think that, in light of new things that we have learned since 2017 about the very bottom bullet point, which is osteocyte apoptosis or necrosis, I think that that now takes on considerable significance when it comes to aging the fracture as closely -- the closest possible time that the fracture may have been to the time of death.
Q. So you were given additional information from the Inquiry team --
A. I was, yes.
Q. -- about the timeline of events and additional information about events in the hospital in particular?

A. Yes.
Q. You were given further information about use of steroids and toxicology information and information about the absence of alcohol in the urine samples.
A. (Witness nods).
Q. And then since 2017 there's been further developments in relation to aging fractures and osteocyte -- either necrosis or apoptosis?
A. Apoptosis, yes.
Q. Thank you. Then can we move on to the next slide please. So this is 26. Talk us through what you have said here?
A. Yes. This is really what we have just discussed. What I was told was that there was no suggestion of an altercation or anything which could have led to the sort of forces that we have been talking about prior to the incident with Mr Bayoh's friend, so I think we can therefore -- if we're looking for a cause of the fracture, then I think we can bring the time line and therefore the means of the cause of the fracture down closer to the time of death.
Q. So from the point at which that altercation took place?
A. Yes. If there was nothing beforehand then I have said, well, in that case then there was nothing beforehand so we brought it down. That of course was the -- was

the -- was the timing furthest away -- I'm sorry, it's a very clumsy way of putting it, but it's the only way I can do it -- the timing furthest away from death that the fracture could have occurred. I have said six hours but it looks as if we can ignore --

Q. Ms Rhodes described it as between 6.30 and quarter to 7 in the morning.

A. Yes, so we know -- and if death occurred around 9 o'clock, we're now limited to that time.

Q. Is this an example of where the actual evidence that the Chair hears and the context in which it is given is a very important element of assessing everything?

A. Absolutely. Everything I have said has to be put into that context. Equally, you know, what I have said has to come into the context as well.

Q. Yes, of course.

A. And we have discussed why I needed to know when the heart stopped pumping and that is both spontaneous pumping and successful CPR. And, as I say, when I read through the notes I'm sure I saw that there was -- a systolic pressure was recorded by the anaesthetist. The heart was being pumped, the lungs were being inflated and inflated with pure oxygen, so any blood that came from the right side of the heart through the lungs to the left side of the heart would have been

oxygenated and the CPR was effectively replacing -- and effectively in every sense -- replacing spontaneous pumping, so I would -- so that's really what that slide is about.

Q. Thank you. Let's move on to the next slide, slide 27.

A. Yes, the toxicological analysis mentioned the presence of MDMA and alpha-PVP in the blood stream. These are psychostimulants and can have, it is my understanding -- though again of course I'm talking as a bone and joint pathologist, not as a toxicologist or whatever -- that these drugs can affect pain perception and can be behaviour changing.

What really interested me was the next set of information about synthetic androgens --

MS GRAHAME: Could I pause for one moment. Sometimes we do require to have a break in the afternoon and it is now 3 o'clock.

LORD BRACADALE: If you think you will finish in about 15 or 20 minutes then I think we could carry on.

MS GRAHAME: Would you be happy -- then we will carry on. Sorry, I just like to check.

So, you have said -- this section is:

"Synthetic androgen: nandrolone~..."

This relates to steroids?

A. Yes. The androgens are steroids. They're in a group of

steroids known as the sex steroids and they have similar effects on men as oestrogens do on women. And that's really where the interest has stemmed from. There are men who develop osteoporosis, just as women can develop osteoporosis beyond the menopause, men develop osteoporosis as a consequence of lowered androgens.

There are two things that I felt were important in the more recent literature from 2017 to late 2022. The first was that the mechanism by which osteoporosis occurs in men with low androgens is that there is excessive amounts of the normal processes of apoptosis, of osteocytes, so removing androgens from elderly men leads to an increase in osteocyte apoptosis, so androgens affect the way in which osteocyte necrosis, as I call them, or what should be better -- osteocyte apoptosis occurred.

There is -- it is just not really known whether the same effects of androgens work in younger men. However, in older men if you give nandrolone, which is the most used of the synthetic androgens, in men who have osteoporosis and osteocyte apoptosis, you can reverse the process using nandrolone. So not only it's an absence of androgen leading to increased osteocyte apoptosis, giving androgens reduces that process. And it struck me that one of the things I needed to consider

was that the -- how that might affect the timing of the osteocyte apoptosis that I had seen and when I came to think it through, I'm afraid I couldn't come to a conclusion.

An argument might be made that by inhibiting apoptosis you would delay the onset of the appearance of apoptosis in bone. The alternative was a slightly more circumferential way of looking at this and that is that we know that the amount of -- we now know that the amount of apoptosis in osteocytes in -- all the way through the male age range perspective reduces, so that -- sorry, increases, so that in infants apoptosis occurs relatively soon -- and we will be talking about the evidence for that -- and that gradually as you get older the amount of apoptosis increases.

That could well mean that what you're doing by giving nandrolone is actually making a man, maybe even a young man -- but there's no evidence for this -- a young man's cells younger, so you're driving the osteocyte into thinking that it's a lot younger than it was and that could then be interpreted that a traumatic cause of apoptosis comes on more quickly because apoptosis associated with fracture is there to initiate healing responses.

Q. So for a young man who has taken nandrolone, one of

these steroids, and sustains a fracture when he is living, ante mortem, will the osteocyte necrosis appear more quickly than it might otherwise have done?

A. That's what I can't work out but the answer is yes, I could come up with a -- I think quite a logical sequence of events that would mean that the apoptosis appeared earlier because the cells were beginning to behave more like the cells of a younger man/child/infant.

Q. Is it fair to say that that's based on your experience and views, but that science itself hasn't quite reached the stage of proving that?

A. No, there's a -- that's quite true. There's a -- there's a lot of androgen usage amongst weightlifters and people in these positions, you know, who are taking them as bodybuilders and there's -- there's a big desire amongst the doctors who run clinics for looking after these people -- because they get lots of other things as well, like liver cancers and so on, or liver tumours -- that they would like to know much more about what the effects of nandrolone are. But you can imagine that that's very difficult because people don't like to say they have been on steroids, how long they have been on, whether they're taking them regularly and so on.

Q. You have said there:

"May change the time closest to death that apoptosis might 1st be seen."

And in terms of the change it would appear more quickly --

A. Yes.

Q. -- is that fair to say?

A. Yes. And there's one more piece of evidence which is on the next slide that might shift a view in that direction.

Q. Let's look at the next slide please. So this is 28. This is your second last slide.

A. Yes.

Q. Can you talk us through this please.

A. Yes. I said right at the beginning of giving my evidence to the Inquiry that I was concerned about the number of people in the country who are in a position to be able to help age fractures -- to help age fracturing, and I therefore went through an analysis of the cases that I had looked at and I looked at three different groups: infants -- and infants are a good group to look at, one because a lot of the work I do relates to aging fractures in infants who may or may not have been abused -- children and adults. And the problem with adults is they span all of these different ages and age is one of the things that we know changes the way in

which cells work, not just bone cells but all cells as part of the aging process.

In order to get a scientific publication accepted you have to show that you have sufficient cases to make analysis worthwhile and when I analysed all my cases going back over 32 years in 2019 I only really had enough cases to make that viable in infants and by that I mean looking -- describing what you see down the microscope against time, so how a fracture heals against time, knowing the time at which the fracture occurred, and in most of the infants at which death occurred. Again, you can imagine that the situation in infants where you're looking at -- a lot of the infants are abused, then getting a time when the abuse might have occurred is very, very difficult indeed.

So any case that fell into that category had to be excluded and so I had I think 171 cases where I knew the age of the fracture and could therefore say: at this age of the fracture these are the appearances that I see down the microscope, this age they are these ones and this age ... and that enables you to say what's the earliest that you have seen a certain event and then the latest. Quite a lot of these events you see something and then it disappears because something else takes its place.

And when I -- just to finish that off, in children there are very, very very few children who come to post mortem, it's just the way it is, and in adults I mentioned that I have had funding for research from the Medical Research Council to look at fractures at many different times, but -- and in my clinical work I was also sent fractured hips and so on that had been removed. But the age range from 16, 18, went up to nearly 90 and so although I had rather more fractures in the adult group, because of this age range I couldn't conduct a proper scientific study and the one thing that was noticeable from that was that I did not have a case in an adult where osteocyte necrosis had been seen before two hours, but I think there were only 32 cases as opposed to 81 children's cases.

Q. That's two hours from death?

A. That's two hours from death, yes.

Q. Prior to death?

A. Yes. But when I analysed the data for infants I found that there was a significant number of cases where the injuring event was known to have occurred an hour from the time of death and in those I saw osteocyte necrosis.

That was really the other piece of evidence that led me to that rather sort of circumferential look -- that's the wrong word but I can't remember what the right word

is, sorry -- to say, well, if you can make osteocytes in adults younger by treating them with nandrolone, could you also push the time before death back towards that of an infant?

There are lots of reasons why that may or may not be the case but it was certainly one of the things that I thought about, so we have -- so we know that this gentleman was taking steroids, it was found in his urine I think, or his blood, and the question was would they have affected the time at which osteocyte necrosis occurred? If they did, is there any evidence that osteocyte necrosis ever could occur less than -- in fractures that are less than two hours old?

And the answer is yes, in the children -- sorry, in the infants it can. So if his osteocytes were being made younger by giving him nandrolone, then could his osteocytes have behaved as if it they were in an infant? Nobody can answer that question, it's impossible. But at the same time an argument I think could be made for saying, well, it's certainly a question that's worth asking and in this case of course it has a lot of implications because of the -- now knowing the time at which death occurred in the terms that I mean by death, that it is pumping oxygenated blood into the tissues, then it does bring it back into a different timeframe,

whereas previously all the timings that I gave would have meant that the police officers would -- that the interactions with the police officers would have been right on the cusp of the timing.

Q. So when we're looking at a two-hour period where you have some evidence in relation to adults, would that be the period between 7.04 and 9.04?

A. Yes.

Q. Would it be as precise as that?

A. No, no, no.

Q. And for infants, if we were talking about infants, would it be the equivalent of between 8.04 and 9.04?

A. Yes, but again --

Q. Not as precise as that?

A. Yes, but roundabout an hour is a good timing to say for those and roundabout two hours for the --

Q. And is that another reason why the circumstances and the context of what's happening are still essential matters for the Chair to consider?

A. Absolutely, absolutely.

Q. Then can we look at your final slide please. This is your views on the fracture from this year and I wonder if you can just take us through those bullet points please.

A. All the evidence points towards this gentleman having

a solitary left first rib fracture and that has a lot to say about mechanism.

I have no doubt that this occurred in life and that is evidenced by osteocyte necrosis and by the presence of haemorrhage, which I demonstrated with the Glycophorin A staining.

It must have occurred less than six hours before death and I have timed death at 09.04 for the reasons I have given and we have already discussed the fact that six hours is probably too far, now we know the circumstances, but again that's not my decision to make as to when that occurred. But I was not told and I don't think the Inquiry has heard of anything that happened that could have led to the sorts of events that we have talked about for this fracture occurring before the fight with the friend.

The nandrolone effects and the data from infants -- and I hadn't analysed my data until late 2018, early 2019 -- would indicate that the certainty that I had that the fracture had occurred more than two hours before death must now be looked at differently because there is -- the effects of nandrolone could have moved the osteocytes back to a similar timeframe in terms of osteocyte apoptosis caused by fracturing, could have moved that back before two hours.

And the -- we have discussed the mechanisms by which this could have occurred and I can see that there would be events that occurred during the altercation with the friend and with the police, which I have timed at roughly 2.5 and 1.75 hours prior to death, which could have led to the sorts of forces that are necessary to fracture his bones. I felt from what I had heard and read and been told that this was more likely to be an indirect injury, so not due to somebody actually physically hitting that bone, and from everything that there was and the descriptions that we have seen of what happened all in the heat of the moment and so on, I still favoured a fall on to an outstretched arm, again because of the absence of soft tissue injuries in a lot of these places and the situation of fractures that are associated with muscular activity, but again not from my experience, from the limited amount of material in the literature.

Q. Thank you very much. Could you give me one moment please.

A. Of course.

(Pause).

MS GRAHAME: Thank you very much. I have no further questions.

LORD BRACADALE: Are there any Rule 9 applications?

Well, Professor Freemont, thank you very much for coming to give evidence to the Inquiry.

A. Thank you, sir.

LORD BRACADALE: I'm very grateful for the care you have taken to make this evidence accessible. I'm going to rise now and you will be free to go.

A. Lovely. Thank you very much.

(3.17 pm)

(The Inquiry adjourned until 10.00am on Tuesday, 23 May 2023)

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