Manchester Arena Inquiry

Day 150

September 21, 2021

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Tuesday, 21 September 2021

(9.30 am)

(Delay in proceedings)

(9.40 am)

MR GREANEY: Sir, good morning. We are now going to hear further evidence in chapter 11 and the evidence today will be from two members of the blast wave panel of experts. We are going to hear from Professor Anthony Bull and Colonel Peter Mahoney, and I will begin by asking each to be sworn.

PROFESSOR ANTHONY BULL (sworn)

COLONEL PETER MAHONEY (affirmed)

Questions from MR GREANEY

MR GREANEY: Gentlemen, do you form two of five members of the group of five experts that we have described as the blast wave panel?

PROFESSOR BULL: Yes, we do.

Q. Have you been provided with instructions to assist the inquiry in relation to certain expert issues?

PROFESSOR BULL: Yes, we have.

Q. Professor, before we turn to those instructions and moreover to your substantive evidence, it's important that we make one thing clear to the public. Is it the position that today you are here to provide your overview evidence only ——

PROFESSOR BULL: Yes, that is.

Q. —— to help us with a series of concepts with which we will become familiar during chapter 12?

PROFESSOR BULL: Yes.

Q. And that as a result, you will not be dealing specifically with events at the arena?

PROFESSOR BULL: That's correct.

Q. Although it may from time to time be relevant to understand whether particular terms and concepts are relevant to our investigation?

PROFESSOR BULL: Yes.

Q. Is it also the position that you will therefore not be dealing with any individual deceased?

PROFESSOR BULL: That's correct.

Q. But that you will return later in our process to deal with events specific to the arena and with the 22 who died?

PROFESSOR BULL: Yes.

Q. Professor, I'm going to begin by asking each of the two of you in court about your qualifications and background and then, professor, I'm going to ask you to introduce us to the qualifications and background of the other members of the panel who are not here today but who did make a contribution to your reports and will give evidence in due course.

Professor, first of all can I invite you to identify yourself.

PROFESSOR BULL: I'm Anthony Bull, I am a bioengineer, I am head of the Department of Bioengineering at Imperial College. I also lead the Centre for Blast Injury Studies, which is an interdisciplinary activity with engineering, medicine and science that investigates blast injuries from point of wounding, mitigation, protection, and rehabilitation.

Q. Does that centre have strong links with the military?

PROFESSOR BULL: Yes. We have military medical and personnel embedded within the centre since we started in 2008. My personal research is in the area of the effect of forces on the human body that cause trauma, but also in other domains such as sporting injuries and performance. Obviously relevant today is those for trauma, specifically blast injury.

Q. Has the centre that you've described conducted world—leading and cutting—edge research and translation activities in understanding blast injury from the point of wounding?

PROFESSOR BULL: Yes, that's correct. Our expertise is unique, there is no centre like this internationally, in particular a centre that incorporates both medicine and engineering, which allows us to investigate the physical

effects and the medical effects and their interaction.

Q. And you've described your extensive experience of trauma research. Is it also relevant to identify that you were rewarded for that work with a fellowship of the Royal Academy of Engineering in 2014?

PROFESSOR BULL: That's correct. In addition, I am a member of the World Council of Biomechanics, where biomechanics is the science of how mechanics, that is forces and deformation, interact with the human body, and there are only 40 members of that worldwide.

Q. Professor, I am going to turn from you, unless there's anything you would like to add, to the colonel and ask Colonel Mahoney to identify himself, please.

COLONEL MAHONEY: I'm Colonel Peter Mahoney. I was a member of the regular army until March 2020 and now I'm a member of the reserve forces. Professionally, I am a medical doctor and my specialty is anaesthesia and I'm a consultant in anaesthesia.

Q. Do you have further additional qualifications in that area of practice?

COLONEL MAHONEY: I do. I have a fellowship in pre—hospital care in addition to my fellowship in anaesthesia and I have a PhD in defence and security, which was an exploration of ballistic head injury.

Q. It is relevant to note that you joined the

Territorial Army in 1980?
COLONEL MAHONEY: I did. So I joined the Territorial Army as a student in 1980 and have seen continuous service up until this point. My deployed service included multiple deployments to both Iraq and Afghanistan, where I was actively involved in the clinical management of casualties suffering from blast and ballistic injury.
I have an additional qualification which is a postgraduate diploma in forensic investigation.
Q. So the simple point is that you have extremely extensive experience of treating blast injuries arising in a battlefield context?
COLONEL MAHONEY: That is correct.
Q. I'm going to turn next to the professor, unless you have anything you wish to add about your background and experience.
COLONEL MAHONEY: Nothing else, thank you.
Q. Obviously, no one could doubt the expertise of the two of you in the issues you're going to help us with.
Professor, I'm going to ask you next to assist us with the background and qualifications of the three additional members of the panel, albeit we'll hear from them in due course. It's helpful to know about it at this stage.
First of all, could, you tell us about Professor,

also Colonel, Jon Clasper? I'm at page 33 of your report.
PROFESSOR BULL: Jon Clasper is the former defence professor of trauma and orthopaedics. He is a consultant orthopaedic surgeon, also retired now from the military.
Q. But I think recently retired?
PROFESSOR BULL: Recently retired. He has seen significant deployments, operational experience, in many places, including Afghanistan. He is a research-active orthopaedic and trauma surgeon with extensive expertise in blast injuries, particularly to the extremities, as relevant to his orthopaedic practice. He has led on the clinical aspects of the Centre for Blast Injury Studies since its inception and so has far broader expertise in that domain and he's a fellow of the Royal College of Surgeons of Edinburgh and of England.
Q. That's extremely helpful. Next, the fourth member of the panel, Alan Hepper, please.
PROFESSOR BULL: Alan Hepper is an engineer. He is a principal engineer at DSTL, the Defence, Science and Technology Lab at Porton Down. In that role, he is the lead on human vulnerability, injury assessment and injury modelling. He has extensive experience of expert witness to the Special Investigation Branch and others and he has been an expert witness on things such as the

7/7 bombings and the Birmingham pub bombings in 1974. He brings expertise in both the physical aspects of the explosion but also extensive expertise in the human injury aspects.
Q. And has, I think, also from my own meeting with him, very extensive understanding of various data which bears upon the work that you do?
PROFESSOR BULL: That's correct, specifically in terms of injury scoring, which is something that I will mention later on, which is how you capture the injuries of individuals in a rigorous way that is comparable to other data sets.
Q. And then finally, and once we've dealt with the fifth expert, I'm going to asking you about how the five of you have worked together, Lieutenant Colonel, also Doctor, Mark Ballard, please.
PROFESSOR BULL: Mark Ballard is a practising radiologist. He is the defence consultant adviser in radiology, so the senior radiologist in the military. He is a head and neck imaging specialist as well as a trauma imaging specialist. He has also deployed to Afghanistan in his military role and he was one of the three radiologists who reported on the CT post-mortems for the victims of the Manchester Arena bombing as well.
He has expertise in many relevant areas, most

notably imaging, but also has published on areas such as the use of tourniquets.
Q. Just to summarise in a few sentences what each of you has brought to the analysis. Colonel Mahoney, would it be fair to summarise your expertise as being the pre-hospital aspect of our analysis?
COLONEL MAHONEY: Pre-hospital aspects and the clinical effects of explosive injury.
Q. Indeed.
Professor Clasper, again seeking to capture this in a few words, but if I don't do it justice, you must tell me, what he has brought to your analysis in particular is his expertise in surgery?
PROFESSOR BULL: And in extremity injuries and bleeding, which is relevant to this subject matter.
Q. Lieutenant Colonel Dr Ballard, the particular expertise that he has brought to bear relates to the radiological aspects of the cases?
PROFESSOR BULL: That's correct.
Q. Professor, the expertise that you have brought to bear relates to the physical aspects of what happens in an explosion?
PROFESSOR BULL: And its relationship to the injuries that arise.
Q. And that Alan Hepper's expertise is complementary to

your own, would that be fair?
PROFESSOR BULL: Including specifically the injury scoring aspects.
Q. Thank you very much indeed. That is a most helpful introduction to the five of you.
In terms of your substantive evidence, I'm going to turn first of all to you, Professor Bull. I'm going to ask you first of all to identify for us what issues you were instructed to assist the inquiry in respect of.
PROFESSOR BULL: We were to describe a description of blast injuries, classifying terms carefully that would then be of use to us as we go forward, describing environmental effects and describing the management of blast injuries.
We additionally and critically, not included today, included a section on survivability for each fatality. To be clear, we weren't asked if the clinical treatment for each individual should have been different; we were asked to comment on survivability only.
Q. Yes. As you have rightly identified, that's a part of your evidence that we're going to leave until you return in order to give your evidence later in chapter 12. Thank you very much.
In terms of your substantive evidence, in your report, and I'm going to start at page 4, you help with the definition of various terms. But the critical

feature that we need to understand relates to the explosive effects of a blast.
The report descends into considerable detail, but as you'll appreciate, we need to avoid being technical to the extent possible to communicate your evidence, although I do understand that that will not be entirely possible. So professor, I believe that it's to you that I should turn to help us with the explosive effects of a blast.
PROFESSOR BULL: Yes. So if I may, I'll start with the seat of the explosion where the explosion takes place. Fundamentally, there are two key things that happen almost simultaneously. The first is that the explosion produces an extremely high pressure wave. So if you imagine a balloon that is blown up and tied, that balloon contains energy within it, and once the balloon is popped, that energy is released, where the pressure goes out from that centre in a spherical way, so it goes out radially and equally in all directions and it carries with it the air and the detonation products, if there are any. It carries that with it behind that pressure wave. So the material that is carried, the air, is called the blast wind, and the wave of pressure that goes ahead of that is called the shock wave or the pressure wave. So you have this high pressure and then

you have this mass of material, air, which is a material, that moves directly behind that.
The pressure wave ——
Q. Can I ask you to pause for one moment? I will do so from time to time. A note is being made by various people and also I need to make sure that I understand two things, a number of things.
So where an explosion occurs, what is created may be known collectively as the blast wave?
PROFESSOR BULL: That's correct, and that is the combination of the shock wave at the front and the blast wind that carries the material behind it.
Q. In case we hear other terms being used, the shock wave, is that also sometimes known as the shock front and sometimes known as the detonation wave?
PROFESSOR BULL: That's correct.
Q. But we can be clear, these two component parts, the shock front and the blast wind, are known together as the blast wave?
PROFESSOR BULL: That's correct.
Q. So I've understood so far. Thank you. Could you carry on?
PROFESSOR BULL: So the features of that are that there is a very rapid increase in pressure at that front, at that shock wave, and that dramatic increase in pressure

occurs within a couple of milliseconds normally. So then you achieve a peak pressure and that peak pressure is a function of many things, but primarily the explosive device itself.
Then we need to bring in the environment here. So in an open environment, a free—field environment, if an explosion were to take place a few metres off the ground ——
Q. So free—field is a technical description that is describing an environment which is entirely open?
PROFESSOR BULL: Which is entirely open and it is purely theoretical because it also assumes that there's no ground there.
So the pressure wave moves out radially in all directions equally. It's an extremely high pressure, but it dissipates very quickly. It dissipates in two ways: by distance and by time. So if one is close, if there is an object close to the seat of the explosion, that object will experience an extremely high peak in pressure and very quickly, within a few milliseconds, that pressure will dissipate fully if one is close. If one is further away, the peak pressure will be far lower and it will also dissipate but a little bit more slowly.
So you have this combination of time and distance and the distance is critical and so I will just explain

very briefly and do stop me if this becomes a little too technical.

By example, if you are 1 metre from the seat of the explosion, and the pressure is, say, 8 kilopascals or a number of 8 higher than normal pressure, let's use that number, and you're 1 metre away, if you go to 2 metres away, that will reduce to only 1 times normal pressure, 1/8. And that is called a cube law. So it's the radius, the distance, times itself, times itself again. So if we go from 1 metre, it's 1 times 1 times 1, the pressure is 8. If you go 2 metres, it's 2 times 2 times 2, it's 1/8 of the original pressure.

Q. Is it too simple to say that the further away from an explosion one is, the less likely one is to be affected by it?

PROFESSOR BULL: Yes.

SIR JOHN SAUNDERS: So it is too simple?

PROFESSOR BULL: It is a little too simple, yes, correct, because it dissipates more quickly. So if one is close, the pressure is experienced by the object. It very quickly dissipates, so if one is 4 metres away, or one is 8 metres away, for both of those it may already have dissipated so significantly that it's negligible. So it ramps up very quickly the closer you get, in this cube power.

That's important when we talk about other types of blast injuries, that specific value, this 1/8 value.

MR GREANEY: The blast wave is made up of these two components and you've spoken of an object being affected by it. Obviously, we are talking here about people, but let's just restrict ourselves to an object at the moment. Do those two different component parts of the blast wave, the shock wave and the blast wind, impact upon that object in different ways or in combination to the same effect?

PROFESSOR BULL: I will describe them in combination to the same effect, but very specifically with primary blast that we will describe later, it is slightly different, so I will refer to that when I get to primary blast.

Q. Shall we leave that until that stage?

PROFESSOR BULL: Thank you. The first is the distance effect. The second is the time effect, this dissipation due to time. That's very important because in a free-field, in this open environment, this idealised pressure wave that one would understand for a blast, you have a rapid peak and then it dissipates really rather quickly. So the area under that curve, if you are to think of pressure and time, is a measure of the impulse or energy that is deposited into an object that comes in the way of that blast wave.

Because the peak is very high, but it dissipates quickly, the energy deposited is relatively low unless there are environmental effects. And by that, I mean that we move from the idealised, open, free-field scenario to perhaps something like an enclosed scenario. So if that balloon were inside a contained space that is closed and that is quite small, relative to the size of the balloon, and the pressure were to increase dramatically when the balloon pops, the explosion happens, there are reflections of that pressure wave off the side of the container, off the side of the enclosed environment that the explosion takes place in.

Q. And off the ground and the roof, I suppose, as well?

PROFESSOR BULL: And off the ground and the roof. That serves to do two things. The first thing is it changes the curve, the pressure/time curve from a peak and rapid decay into a peak and multiple reflections, and secondly, that means that the area under the pressure time curve is much, much greater than the idealised and so there is far more significant energy deposited into an object that is in its environment. That also means that the peak pressure is maintained for longer and for further from the seat of the explosion.

Q. So I did tell you that from time to time we would need to focus in on Manchester Arena and on the City Room.

You have described free-field and enclosed space. Obviously, the City Room is enclosed in one sense, but when we come on later in your evidence to consider environmental factors, should we regard the City Room as being an enclosed space or as something different?

PROFESSOR BULL: Okay. So for it to be an idealised enclosed space, the pressure would have to be contained. And that was not the case in the arena, first.

Secondly, the pressure would have to -- the volume within which the pressure could be dissipated would have to be small enough for it to have a significant effect, and the arena is very large. So based on our expertise, we would class this more akin to an open, free-field type of blast rather than an enclosed blast, even though it occurred within a building.

Q. So far, we have been talking about a balloon and a balloon popping. Obviously, we are here concerned with something far more terrible than that and I want to move next to understand a bomb of the type that we are concerned with and how that relates to the kind of issues you have been telling us about. I am at page 8, I think, of your report.

SIR JOHN SAUNDERS: Do you mind if I just ask one thing? This is probably a very naive question, so please forgive it. You have talked about a shock wave and

a blast wind being these two components and, obviously, the blast wind is made up of air. Is the shock wave made up of anything?
MR GREANEY: I think we're coming to that, sir.
SIR JOHN SAUNDERS: Thank you. Okay.
MR GREANEY: It's an entirely sensible question, but I promise we are coming to it.
SIR JOHN SAUNDERS: That's entirely fine. Deal with it in your own way.
PROFESSOR BULL: The shock wave is the transmission of energy through the material, so the material is the air but it's not necessarily moving air. One can understand that in the context of maybe a piece of metal, and if one were to strike a piece of metal, the metal itself is not moving anywhere, but there is, as you would hear, some resonance, there is a wave transmitted through that piece of metal. Effectively, that's happening with the shock.

So the shock is the pressure being deposited through that, but it's not the energy being brought through, which is the mass of air behind it. So it's the way pressure is transmitted through a material. It can happen through glass, it can happen through metal, it can happen through air and water as well.
Q. I have probably entirely misunderstood this, and

if I have you'll tell me, but the blast wave is itself capable of causing injury, the ways in which you're going to come on to describe?
PROFESSOR BULL: Yes.
Q. The shock wave, rather, is capable of causing injury ——
PROFESSOR BULL: Yes.
Q. —— in ways you're going to describe. But the shock wave itself, if there has been a bomb of the type we are concerned with, that will not carry the fragments?
PROFESSOR BULL: No. Should I explain that?
Q. Please do.
PROFESSOR BULL: The blast wind that comes behind the shock wave carries material with it, explosive products, et cetera, the air. But there are also fragments, so some fragments come from the device itself, these are called primary fragments, and some fragments might be from the environment around it that are energised by this blast wind and those are called secondary fragments. But we have fragments, we have material that is energised by the blast wind, and this is then carried radially again, because the energy is going out in the same way, so equally in all directions in an open field environment and travels distance.

What is different is, because of the way the laws of physics work, that the energy that is contained within

one of those fragments now, so energy is deposited into a fragment, it is accelerated and it is transmitted out radially. It now has its own energy, kinetic energy, moving energy. That dissipates over time as well, so if one were to fire a gun with a certain velocity, it would reduce its velocity over time, over distance.

The amount of energy that it loses is slower than the amount of energy that is lost by the shock wave. So if one were to double the distance, the energy it holds is now one quarter, whereas for the pressure wave, for the shock wave, it is one eighth. That's key. So what it means is that the fragments can cause harm to an object at a far longer distance from the seat of the explosion than the shock wave itself in a radial direction, with direct line of sight.
Q. I'm going to turn in a moment to look, as is very important, at the type of injuries that may be caused by an explosion. But what I'm going to do before we turn to that is to see if I can express the evidence you've given in a few simple propositions and, again, if I oversimplify this you must tell me because I do tend to do that.

An explosion generates high pressure, which is transferred into the surrounding area?
PROFESSOR BULL: Yes.

Q. That high—pressure front travels out very quickly indeed, indeed quicker than the speed of sound?
PROFESSOR BULL: Correct.
Q. We might describe that as the blast wave?
PROFESSOR BULL: Yes.
Q. That blast wave has two components: the shock front and the blast wind?
PROFESSOR BULL: Yes.
Q. And that blast wave lasts for a very short period of time, we're talking thousandths or hundredths of a second?
PROFESSOR BULL: Correct.
Q. Where the explosion is the result of an explosive device, on explosion the device will fragment?
PROFESSOR BULL: Correct.
Q. And the fragments of the device and anything with which it is packed, in this case, as we know, with nuts, will be thrown out, and we would describe those as being primary fragments?
PROFESSOR BULL: Correct.
Q. But also, the effect of the blast wave may be to move other items which are within its environment?
PROFESSOR BULL: Yes.
Q. So a stone, for example?
PROFESSOR BULL: Correct.

Q. And those will be described as secondary fragments?
PROFESSOR BULL: Yes.
Q. So have I understood so far?
PROFESSOR BULL: Yes, you have.
Q. And have I oversimplified where we have reached?
PROFESSOR BULL: I think that's sufficient.
Q. I'm going to turn next to page 9 of your report, and again Professor Bull, in the first instance, you're going to help us with this. It's the classification of blast injuries. And then we'll turn to the colonel to help us with the medical effects unless, sir, there are any further questions you have about the physical aspects of an explosion.
SIR JOHN SAUNDERS: No, thank you.
MR GREANEY: Again, over to you in the first instance, professor, and at the end I will see if I can apply some simplification if it has become complicated.
Could you explain to us the five main categories of blast injuries, albeit I do appreciate in relation to the fifth there is controversy.
PROFESSOR BULL: It may be helpful to bring up figure 3.
Q. Indeed, yes. Could we have, please, Mr Lopez, on the screen -- and don't put it up until you have focused in on the figure -- figure 3. This is {INQ025364/9}.
If you can just have the figure on the screen, that

would be extremely helpful.
Just before you put it on the screen, sir, could I just make sure everyone is aware, this is an image that we did look at on the screen during the course of our opening statement back in September of 2020. It is not overly graphic, but it does demonstrate what happens in an explosion and I just wanted to give that warning to everybody before we see it. It doesn't show real life, but it does shows the effects of an explosion.
The phases and the categorisation of blast injuries, please, professor.
PROFESSOR BULL: Yes. We will start with primary blast injury. This peak pressure, the shock wave, that is transmitted, I think it's helpful to explain again in terms of a bar of metal. If the pressure wave, if one hits the bar of metal at one end, the shock wave, a wave, is transmitted through that metal and in and of itself it is not damaged.
However, if one were to have a material placed on the end of that bar of metal, maybe another rod, maybe some other material, and one were to hit that bar of metal and the wave were to be transmitted along it, then the material at the end would separate from it, the material that was in contact with it.
So what happens when a shock wave comes into contact

with an object, and with a person in this case, the first material that it comes into contact with, let's say the skin, the muscle, the tissues, have the pressure wave transmitted through it. But where the tissues have a margin between them, so let's say between muscle and bone, or let's say between air and the tissues of the lung, then, like the metal bar and the material placed on the end of it, there is disruption at the interface, the pressure wave goes through and then where you have an interface, there is shearing, a separation of the materials at that interface.
That's particularly significant where you have materials of very significant density such as bone and air, fluid and soft tissues. They have different densities and so you end up with disruption at those interfaces, so that disruption is a primary blast injury.
Q. So we are not talking here about the object, a person, being struck by any fragment of a bomb, we're just talking about the shock wave?
PROFESSOR BULL: It's that peak pressure that occurs for a very short period of time in a free-field environment, which is what we're talking about, an extremely short period of time. If the person is close to the seat of the explosion, then that pressure wave is transmitted

through the person and at the interfaces there is disruption and shearing of the tissues.
Q. You talk about shearing of tissues.
PROFESSOR BULL: Tearing.
Q. So the shock wave itself, as we're going to hear from Colonel Mahoney in due course, is capable of causing injury, indeed serious injury?
PROFESSOR BULL: Yes.
Q. And in this context we're going to look with the colonel in due course at, for example, blast lung. So that is primary blast injury caused by the shock wave itself?
PROFESSOR BULL: And I think it's worth clarifying here that there is confusion in many places where people refer to "blast injury" in general but mean primary blast injury. However, the subsequent blast injury mechanisms that I will refer to now are also included under that, and we just need to be careful.
Q. You refer to this in your report. There is an issue of terminology. When you use the term "blast injury", you are describing primary through to quinary. But sometimes in the literature, "blast injury" is used to describe what is more precisely described as primary blast injury?
PROFESSOR BULL: That's correct.
Q. So we will be careful about our terminology.

SIR JOHN SAUNDERS: Just before you go on from primary blast injury, in the case of the City Room are we considering reflecting shock waves as well as ——
PROFESSOR BULL: No, we're not.
SIR JOHN SAUNDERS: So we can, as it were, delete "and reflecting shock waves" because, although it is part of the principle, it doesn't actually apply in this case?
PROFESSOR BULL: That's correct, sir.
MR GREANEY: When you return, we are going to look at the actual relevance of primary blast injury in our circumstances, but now I hope we do understand what primary blast injury is: these are the injuries caused by the shock wave itself and we'll understand that from a medical perspective in a short time.
Can we turn next, then, to secondary blast injury?
PROFESSOR BULL: So the blast wind is accelerating these fragments, projectiles, effectively, and, if you recall, the energy is dissipated more slowly than the peak pressure, the shock wave.
Q. Yes.
PROFESSOR BULL: Effectively, these cause anatomical deficit. They come into contact with the person and they disrupt the anatomy: they tear the anatomy, they push holes through the anatomy. This is like being hit by —— being shot, but it's typically worse than that

because the fragments don't only contain energy going in a straight line, they also contain rotational tumbling energy, which is a function of the shape of these fragments, and that tumbling energy causes more significant tearing of the anatomy that it comes into contact with.
So very specifically, this is where anatomy plays a major role in blast injuries because it's always very specific to the very specific projectile and the very specific anatomy that it has disrupted.
Q. So obviously, being struck by a primary and secondary fragment is going to be terrible, a terrible event whatever, but if one is struck in the head or in the heart, that is inherently going to be more serious than being struck in another part of the body or other parts of body?
PROFESSOR BULL: Yes, that's correct, and Colonel Peter will be referring to that later on. I think it is worth just highlighting that there is this line of sight issue, where clearly if there are objects between the explosion and the individual, then one can imagine that there isn't an equal statistical chance of being struck by one of these fragments. The explosion may not be perfectly detonated and so the pressure may be slightly higher on one side on the other, there may be little peaks of

pressure that then accelerate fragments in one direction more than another, so it's not just a perfect situation in general.
So these fragments can travel a very long distance, but they may only travel a very long distance in one way and not in the other way.
Q. When we talk of secondary blast injury, we're talking not just of injury caused by primary fragments of a bomb in this case, but also what you've explained to us as secondary fragments as well?
PROFESSOR BULL: That's correct.
Q. I'm just going to pause for a moment. I am aware that some have left the room, which I completely understand. As I explained yesterday, I recognise that this evidence, which is being expressed in technical terms, but which has caused enduring loss to so many, is inevitably going to be distressing. I regret that, but see no other way of doing it.
SIR JOHN SAUNDERS: There is no alternative. It has to be gone through, as everyone accepts, and you have indicated and pre—warned people, which is I think all that can be done. What might be helpful now, if you're able to say so, is to give some rough idea of how long this evidence is likely to take before we get on to the next stage when people might wish to come back.

MR GREANEY: Sir, I think that this evidence will take until no later than midday, that's my prediction.
I anticipate that Ms Cartwright will provide the information she wishes to provide at some stage before we break for lunch at 12.30, so if we set a time now of 12.15, and then we will commence the evidence in chapter 12 at 1.30.
SIR JOHN SAUNDERS: Thank you very much.
I wonder if people could convey that to —— the family CPs can convey that to the various people who have perfectly reasonably left.
MR COOPER: Of course, sir. I can reassure all within the hearing that all family CPs, I know, have spoken very carefully with their clients who attend to endorse what has been said. Whether perhaps a few more breaks than normal in proceedings might help so that we could speak with families who may be upset, I'll leave that to the discretion of the inquiry.
SIR JOHN SAUNDERS: Okay.
MR GREANEY: That sounds like a sensible invitation to have a short break at this stage and I'm very grateful to Mr Cooper for helping us to manage this in a sensitive and helpful way.
SIR JOHN SAUNDERS: Okay. If we have our quarter of an hour break, that would be a good idea.

I'm sorry to interrupt your evidence, I'm sure you'll understand. Thank you.
(10.24 am)
(A short break)
(10.39 am)
MR GREANEY: Sir, thank you, we're going to continue with the classification of blast injuries. I'm going to ask that we have back on the screen figure 3, please, and that the professor then helps us in relation to tertiary injuries, please.
We've dealt with primary and secondary. What are tertiary injuries as a result of a blast, please?
PROFESSOR BULL: If we just refer back to the concept of energy being deposited into an object, there are injuries that occur when someone themselves has the energy deposited, almost like a blunt deposit, so they are then displaced by the blast wind. And do that displacement can be very rapid in some instances and therefore, as they are displaced, they can have accelerative injuries that could be due to internal accelerations or they can have crush injuries, where they come into contact with something hard. That is one form of tertiary blast injury.
Another form of tertiary blast injury is sometimes called solid blast and that is when something else has

been energised, it might be the environment itself, it might be the building, and large material, not fragments any more, but large material comes into contact with the individual. That then also produces crush injuries. So either the individual comes into contact with something hard or something hard comes into contact with the individual.
SIR JOHN SAUNDERS: When you're moving the body, is that caused by the blast wind?
PROFESSOR BULL: Yes, it's caused by the blast wind as the mass of air energises the individual.
SIR JOHN SAUNDERS: Because the shock front passes through?
PROFESSOR BULL: Has gone through, yes, that's correct. Just to be clear, and maybe Colonel Peter will comment on this, the energy involved is far higher than one would see in, for example, a road traffic accident or something like that. So these crush injuries can be far more severe in tertiary blast.
SIR JOHN SAUNDERS: Okay. I may be being unduly optimistic but that seems a fairly simple concept to me as compared perhaps to the primary blast injury, which is more difficult to understand.
MR GREANEY: I agree, sir, although hopefully we understand each of them so far.
That's all I want to ask you about tertiary blast

injury. Quaternary blast injury, please.
PROFESSOR BULL: This is relevant. It's caused by heat and clearly when you have an explosion, heat is given off, and so burns and inhalation injuries can occur. This is also a more straightforward concept.
Q. And then finally, the concept over which I know there is some controversy, quinary blast injury, please.
PROFESSOR BULL: Yes. There are different ways of describing this, but perhaps we could describe it most simply as all the other types of injury that could occur due to blast. For example, biological injury where there may be biological contaminants or radiological injury where there are radiological contaminants. And of course these effects can be immediate but they can also be long term.
SIR JOHN SAUNDERS: Do we need to go into why this is controversial?
MR GREANEY: I think you can probably express it in a couple of sentences, in the way in which you do in your report.
PROFESSOR BULL: I think because some people would say that because certain of the injuries that I have just described, let's say radiological, they don't appear directly as a result of something that is associated with the blast wave or the blast wind, it's more the contaminants, and so people would then not describe that

as a blast injury. But because it occurred due to the explosion, others would class it as such.
SIR JOHN SAUNDERS: So whether you call it a blast injury or something different, it's still an effect of a blast taking place?
PROFESSOR BULL: Yes, sir.
MR GREANEY: It's kind of a direct/indirect type issue?
PROFESSOR BULL: That's correct.
Q. Although, I think in fact, as we are going to learn when you return, that's not really something that we need to be concerned go in the context of the Manchester Arena attack.
PROFESSOR BULL: No, not specifically.
Q. In your report, you deal with environmental features and device proximity in considerable detail. Obviously, in dealing with this we need to be very alert to the need not to provide information of assistance to those who would wish us harm. Is there any particular feature that falls under that heading, environmental features and device proximity, that you believe it is important to draw to our attention that we have not dealt with so far?
PROFESSOR BULL: I don't think so.
Q. Nor do I. So professor, I'm going to turn from you, please, for the time being, to Colonel Mahoney.

Colonel, I'm going to ask you to deal with what again will be a distressing aspect of the evidence for in particular the bereaved families, so I give that warning. I'm going to ask you to help us with the medical aspects of each of those types of blast injury which Professor Bull has described to us in physical terms.

I'm at page 9 of your report. So first of all, primary blast injuries. What type of injuries from a medical perspective are we concerned with here?

COLONEL MAHONEY: If I may, I think it would be very helpful to start with a description of fundamental physiology.

Q. That would indeed be helpful, thank you.

COLONEL MAHONEY: If we think about what we need to be alive as human beings, fundamentally we need oxygen and other vital nutrients delivered to the cells or key organs. So I need oxygen delivered to the cells in my brain. To do that I need blood, I need blood flowing in intact blood vessels. And for the blood to flow, I need a heart that's pumping. And then to get oxygen into the blood, I need lungs that are working. So that fundamental physiology is what's keeping us alive.

Q. So that's very important to understand in terms of the injuries that you're going to describe?

COLONEL MAHONEY: Yes.

Q. And moreover, it's very important, very, very important, to understand in terms of how those injuries are to be managed if life is to be preserved?

COLONEL MAHONEY: Yes, it is.

Q. Thank you very much for providing us with that context. Against that background, are you content now to turn to deal with these different classifications of injuries and what they mean medically?

COLONEL MAHONEY: Yes, I am. When we're talking about primary blast injury, we're particularly concerned with the effect that has on the lungs and, as has been described by Professor Bull, we're talking about energy being delivered into the body and the effect of that energy is to sort of pull and push the delicate structures of the lungs and disrupt those delicate structures, causing bleeding and by causing bleeding within the structure of the lungs, the amount of lung that is available to exchange oxygen into the body and remove carbon dioxide from the body is reduced.

Q. Just pause for one moment. As I understand it, understandably you're focused on the lungs, for reasons everyone in this room will understand. But the kind of effect you're talking about can occur within any of the air-containing organs, so the lungs, airway and bowel?

COLONEL MAHONEY: It certainly can. And not only that, it

can also occur in organs such as the brain. The brain is a structure full of lots and lots of complex -- effectively complex cables and complex cells all working together and that same pushing-and-pulling mechanism can disrupt the structure of the brain and cause significant injury within the brain. So there's the air-containing organs that are particularly vulnerable, but you can also get energy delivered to other organs.

Q. Sorry to interrupt you but this is obviously important. Are these injuries that can occur without any external signs on the body?

COLONEL MAHONEY: There are injuries that can occur without external signs on the body. If you have significant lung disruption without obvious external injury, that can be caused by a blast wave. You can also get significant brain injury without obvious external signs. You'd expect to pick those up in subsequent examination with CT scans and subsequent post-mortem examination, but it is entirely possible, when you're looking at an individual lying on the ground in front of you, you might not see obvious signs of injury.

Q. I took you away from the lung. I would like to go back to the lung now. Is there a particular type of primary blast injury to the lung that is encountered?

COLONEL MAHONEY: There is a circumstance in which you're

likely to find it and that's within closed environments because of the increase in pressure as has described already.

Q. Is there is a term that's described to the type of injury you're going to tell us about?

COLONEL MAHONEY: The term that is used is blast lung, which again describes the primary injury to the lung. Blast lung effectively is a mixture of the bleeding, as I've described, and subsequent inflammatory reaction to that bleeding.

SIR JOHN SAUNDERS: Bleeding and? I'm sorry, I missed the second part.

COLONEL MAHONEY: There's the initial injury is bleeding caused by disruption of the structure of the lung and the result of that is an inflammatory response from the body, which means that it becomes a progressive injury, an injury that develops over a number of hours and becomes worse over a period of time.

SIR JOHN SAUNDERS: Thank you.

MR GREANEY: You did mention it, the type of location in which that might be more common. I'm going to leave that for one moment, we will come back to it.

Is it possible to express a view about how dangerous blast lung is or may that depend upon the particular circumstances?

COLONEL MAHONEY: It's very situation dependent. So there are reports in the open literature of individuals who have died purely of blast lung in certain environments. And from our own military experience, we have cohorts of individuals who have survived blast lung with the correct higher—level care. But the key thing to remember is in the incident that we are discussing, it hasn't happened in isolation, and we have to consider the overarching effect of all these injuries taken together.
Q. I entirely understand why you say that and obviously we are going to come on to look at that in detail when you return.
SIR JOHN SAUNDERS: So in no case that we are considering are we considering an incident of someone dying purely from blast lung?
COLONEL MAHONEY: Correct, sir. No one purely from blast lung, sir.
MR GREANEY: I keep saying this, when you return, we will need to look at the preponderance of blast lung amongst the 22 people that we are concerned with.
So a very dangerous condition to suffer from, but not necessarily fatal of itself?
COLONEL MAHONEY: It can be fatal of itself in some circumstances, if you're very close to an explosion and

you have a very significant load, which then disrupts such a large proportion of the lung there is insufficient lung left to allow that oxygen exchange that I have described earlier. So it can be a fatal injury, but it can also occur in individuals who survive. But by virtue of its presence, it will interfere with the body's ability to manage the other injuries. So in the presence of blast lung, a bleeding injury will be more severe because they can compound their effects.
Q. To provide an overall injury profile, which is obviously something we're going to have to look at in detail in due course.
There are two further aspects in blast lung, still seeking to deal with matters in general terms, and then we'll move on to secondary blast injuries.
SIR JOHN SAUNDERS: Just on the mechanics, in very simplistic terms, the mechanics when it does cause death on its own, is it's preventing getting enough blood in the lungs for the oxygenation of it to go to the brain?
COLONEL MAHONEY: There's a number of reported mechanisms, sir, one of which is it's effectively a wholesale destruction of the lung tissues, causing tearing and big air leaks so the lungs are no longer functioning as

gas—exchange mechanisms. It can be the amount of bleeding into the lungs which is impeding the exchange of oxygen, and also a proposed mechanism is that gas, oxygen, air, particularly air, can be driven through ruptured vessels into areas where it shouldn't be. So instead of air exchanging across the lung surface, it's directly forced into blood vessels and in effect becomes what is called an embolism and can go round the circulation and cause blockages in vital parts of the circulation.
SIR JOHN SAUNDERS: The essential feature in all of those is a prevention of oxygenation of the blood?
COLONEL MAHONEY: A significant part of the tearing, the bleeding and loss of lung function is an impact on the ability to oxygenate the blood and the impact of embolisation is to prevent circulation to vital parts of the body.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: So two aspects before we move on. First of all, does it follow from what you have said that proximity to the explosion is of a high degree of relevance to whether one experiences blast lung and, if so, how severely one does so?
COLONEL MAHONEY: Yes.
Q. Secondly, you referred to enclosed spaces. Is it of

relevance to whether one suffers blast lung, and if so how severely, whether one is in an explosion in an enclosed space or elsewhere?
COLONEL MAHONEY: Yes. If you look at the open source literature, there's a higher incidence of casualties with blast lung in environments, closed environments, such as buses and tube trains.
SIR JOHN SAUNDERS: And the City Room is not, in your terms, a closed environment?
COLONEL MAHONEY: No, sir, it is not a closed environment. So to have blast lung in this context implies a proximity to the explosion.
SIR JOHN SAUNDERS: I understand that.
MR GREANEY: That's what I wanted to be clear about: the fact that we are not concerned about what you describe as an enclosed space does not exclude the possibility of blast lung, it reduces the prospect of it occurring, but obviously one needs to take into account proximity to the explosion?
COLONEL MAHONEY: Yes.
Q. That's all I wanted to ask you about primary blast injury. Is there anything else you'd like to add before we move on to secondary blast injury?
COLONEL MAHONEY: No, thank you.
Q. Secondary blast injury, please. This is injury

resulting from the impact of fragments. From a medical point of view, what injuries does one expect to occur?
COLONEL MAHONEY: The injuries that you'll get from impact of fragments, or the effect that you'll get from the impact of fragments, will depend on which part of the body is being hit. I appreciate that this —— by necessity I have to describe certain injury types.
Q. We will pause for one moment and I'll fill the gap by asking you to confirm that you're moving on to deal with what the professor was telling us about earlier, that obviously the severity of a secondary blast injury will depend upon the location that is struck?
COLONEL MAHONEY: Absolutely.
Q. So I've created a pause and thank you very much for your caution. You are entirely right that, sadly, we do need to understand more about this.
COLONEL MAHONEY: If we take a fragment, say, that has struck somebody in the head, and they suffer a significant brain injury, that could be a rapidly fatal injury. If we take somebody who has been struck by a fragment in the heart or a very big blood vessel, that can be a rapidly fatal injury due to disruption of the function of the heart or causing rapid bleeding from loss of a major blood vessel.
If a fragment has penetrated the lungs or perforated

the lungs, a perforation going all the way through, penetrating, entering and not going all the way through, then that in itself can disrupt the function of the lungs and create an air leak. Indeed in the presence of the primary injury, that could compound the effect of the primary injury.
A fragment could impact with a limb and cause a breaking of bones and impacting on the individual to move, stand up, use their limbs, and if that fragment impacts on blood vessels associated with that area of the bone, it will also cause bleeding.
Q. I'm going to ask you to confirm one paragraph of your report because I am confident Mr Weatherby would wish me to do so. It's at page 10, paragraph 2.32 —— or at least part of that paragraph:
"Injuries that involve the brain or heart are the most serious and can cause immediate death. Whereas damage to blood vessels or the lungs can cause early death, but there may be sufficient time for medical interventions to save life."
COLONEL MAHONEY: Correct.
Q. "When bone is struck, a fracture can occur but this is unlikely to threaten life unless this is associated with damage to a major blood vessel."
COLONEL MAHONEY: Correct.

Q. Subject to any questions that the chairman may have, that's all I wish to ask you about secondary blast injury. Is there anything that you wanted to add before we moved on?
COLONEL MAHONEY: No, sir.
Q. So next, then, tertiary blast injury. From a medical perspective, what sort of injuries would be expected to result?
COLONEL MAHONEY: I think the best way to consider it is very much like people falling, impacting with the structure or decelerating. So the type of injuries can be what we would describe as blunt injuries.
I mentioned secondary injuries were penetrating or perforating ——
MR GREANEY: You did.
COLONEL MAHONEY: When someone is being thrown either against an object or being hit by a large object, you would expect to see fractures, you would expect to see surface bruising. And if it's hard enough, you might also see disruption of internal organs.
Q. And I think that probably is all we need to say about tertiary injuries; do you agree?
COLONEL MAHONEY: I agree, yes.
Q. Quaternary blast injury we can deal with swiftly: that is injury caused by heat, which may cause burn and/or

inhalation injury?
COLONEL MAHONEY: Yes. It's a result of either burns from the products of explosion or burning from other materials in the environment being set on fire, such as clothing or furniture.
Q. Then finally, quinary injury. I don't believe we need to go into that at all unless you ——
COLONEL MAHONEY: Not for this, sir, no we don't.
MR GREANEY: I'm going to come on to a connected topic in a moment, but sir, that's all I propose to ask about the medical aspects of the blast injuries.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: I believe, colonel, that you consider it would be helpful for us to understand an issue that you address at page 15 of your report. This is your first report, your overview report, {INQ025364/15}.
The heading is:
"Internal blast injury with no external evidence of trauma."
COLONEL MAHONEY: Yes. We talked briefly about that when we were talking about could you have primary blast injury or could you have fatal primary blast injury without external evidence of injury, and we've covered that.
But in addition, you could have somebody who dies

from a very small fragment entering around the hairline or in through the orbit, and causing brain injury, and that might not be immediately noticed -- or you'd expect to pick that up perhaps on CT scanning. You could have small fragments that enter the chest and disrupt the heart function and you might not see that on initial external examination, but you would expect to see that if you did a subsequent CT scan.

Q. Next, I'm going to turn to the very important topic of the management of blast injuries, and again, colonel, this is a topic for you. I'm at page 17 of your report.

Is the basic point that the extent to which lives may be saved depends upon obviously the nature of the injury that has been sustained, but also upon the appropriate and early management of those injuries?

COLONEL MAHONEY: Yes, it is.

Q. Obviously, some injuries will be, as we're going to hear, unsurvivable wherever they occur and whatever treatment is given at whatever stage?

COLONEL MAHONEY: Absolutely right. We've talked about that, we've talked about severe head injuries and direct injuries to the heart and to major blood vessels where the injuries are so catastrophic, no intervention will save that individual. Again, appreciating that this will be upsetting material, these can be people who are

killed instantly or who die within a very short space of time, and we're talking seconds to minutes.

Q. But some injuries, as is obvious, will not be as catastrophic or as immediately catastrophic as that?

COLONEL MAHONEY: That is correct.

Q. If the injury one is concerned with is the victim bleeding badly from an area of the body, what action may be life-saving?

COLONEL MAHONEY: I think what's key is when we're talking about bomb blasts and ballistic-type injuries, certainly within the military we had to think in a different way to the way we were thinking at the beginning of the conflicts in Iraq and Afghanistan. At the very beginning of those, we took civilian protocols and effectively implemented them, but it became very clear that the prevalence of severe bleeding injury meant we had to think differently. And the result of that --

Q. When did this re-think start?

COLONEL MAHONEY: This was from 2003 onwards.

Q. Right.

COLONEL MAHONEY: Recognising that the sort of penetrating injury, the perforating injury, the limb-removing injury of explosions meant we were faced with people who were bleeding very rapidly and very significantly. So we moved from a paradigm of standard first aid, which was

to manage airway, breathing and circulation, to a paradigm where we would manage catastrophic bleeding followed by airway, breathing, circulation.

This links with the question you have asked, sir. If you're faced with somebody who is bleeding badly, with the correct treatment for an injury that's amenable to stopping bleeding, you can save that person's life. And the correct treatment is simple measures. We're talking about external bleeding, so somebody bleeding from an injured arm or injured leg. You may go to pressure, putting pressure on it to try to compress the vessels and stop the bleeding, probably go to elevation, if their injuries allow that, to minimise the blood flow to that limb, and you may go to a tourniquet.

If you're faced with a very severe injury, you may leap those first two stages and go immediately to a tourniquet.

Q. Is the ability to apply tourniquets dependent upon the location that the bleed is coming from?

COLONEL MAHONEY: Yes, it is. There are some injuries which are not amenable to treatment with a tourniquet and there are some that are amenable to treatment with a tourniquet.

Q. So there has been, since 2003, a development of thinking?

COLONEL MAHONEY: Yes.

Q. An increase in understanding?

COLONEL MAHONEY: Yes.

Q. Based sadly upon the fact that the military have encountered this type of injury all too commonly?

COLONEL MAHONEY: Yes.

Q. Has the learning that comes from the battlefield been translated and had it been translated into the civilian population by 2017?

COLONEL MAHONEY: Some of it has. Certainly within the ambulance services, there was a much greater awareness of tourniquets and the thought processes of jumping immediately to a tourniquet under certain circumstances. And some of the other learning that we brought about, our resuscitation protocols beyond first aid, have also come into the National Health Service.

Q. The type of bleed that we have been speaking about, which may or may not be amenable to a tourniquet depending on location, is postulating an external bleed?

COLONEL MAHONEY: Yes.

Q. But there may be an injury which results in no or no significant external bleeding but internal bleeding?

COLONEL MAHONEY: Correct.

Q. In the context of such a blast injury, how is that to be managed to save life or with a view to saving life?

COLONEL MAHONEY: What we'd look to do would be to either do the fundamental basics well, so address any obvious external bleeding, address any obvious airway issues, any obvious breathing issues, and if the person was not responding to that and they had signs of injury, recognise the fact that it was likely internal bleeding was taking place and aim to evacuate them as quickly as possible to a hospital so that they could undergo life-saving surgery.

If you have internal bleeding and you can't deal with that at the site of the incident, then really you're thinking about doing what you can to keep that person stable, but you're looking at a move to a hospital to get expert surgical care.

Q. You mentioned airway and so what one might encounter is a situation in which the victim is unconscious and there is some blockage in their nose or mouth preventing breathing; is that the type of situation we're dealing with?

COLONEL MAHONEY: That's correct. What you could have, you could have somebody who had been sucking a sweet before they were hurt and that sweet has blocked their airway or somebody who's been rendered unconscious and fallen in such a position that their tongue is obstructing their airway. And what we would look for people

attending the casualty to do would be to carry out manoeuvres to unblock the airway, remove any obstruction, and position their head, neck, airway in such a position that it was then clear and you could allow the unimpeded movement of air.

Q. And the kind of steps to clear any obstruction, are they as simple as the steps that I have in my own mind, simple steps?

COLONEL MAHONEY: Yes. Let's say we've got somebody where the anatomy has not been injured, so as you look at me now, as I look at you, with normal anatomy, then the steps are relatively straightforward and are taught as part of basic first aid training. We're talking about what's called a chin lift, a jaw thrust, and for people with more advanced first aid training, they may be taught to look in the mouth, look for obstruction, use suction apparatus to remove any food or fluid that's obstructing. So they are relatively simple procedures in the absence of difficult anatomical injury.

Q. So where we have reached is that in terms of managing blast injuries, what needs to occur if there is to be a chance of saving life is dealing with a catastrophic bleed?

COLONEL MAHONEY: Yes.

Q. And managing an airway?

COLONEL MAHONEY: Correct.

Q. We're going to turn to burden of injury in a moment, but before we do is there any other factor or feature that you'd like to draw to our attention in relation to the management of blast injuries?

COLONEL MAHONEY: So if an individual had a hole in their chest from a fragment and that was impacting on the mechanism of breathing, then if somebody had the appropriate first aid training, you'd look for them to cover that hole.

Q. So far, we've been speaking about the victim of an explosion on the basis that they have one injury, that the person managing them has to deal with, but is life as simple as that?

COLONEL MAHONEY: Rarely in explosions, sir, rarely.

Q. So will, in an explosion, those responding commonly encounter victims who have multiple injuries?

COLONEL MAHONEY: Yes, they will, and that was the situation we frequently encountered in Iraq and Afghanistan, which is why we developed the paradigm I mentioned earlier of the ABC, which was building on first aid knowledge that has existed for many, many years, to identify what injuries are the most immediately life-threatening, manage those quickly, and then move to other injuries.

So in the presence of multiple injuries, we would

look to identify catastrophic bleeding and deal with that and then move on to airway and move on to breathing and move on to subsequent injuries.

But it can be very, very difficult and I think it can -- if it's not something you have dealt with very often, it can be almost overwhelming when you see the nature of these injuries.

Q. I'm going to just read to you one paragraph of your report in a moment and invite you to confirm it:

"The CABC..."

Can you just remind us what that stands for?

COLONEL MAHONEY: CABC stands for management of catastrophic bleeding, such as that caused by a big injury to a blood vessel, where you have catastrophic external obvious bleeding, and then moving on to manage airway and then breathing issues, then other circulation issues. Other circulation issues might be things like less severe bleeding. Then you move on through a whole series of systems to recognise and deal with other injuries.

Q. In your report, page 17, paragraph 5.8, you observe in connection with this issue of multiple injuries:

"Whether or not a victim survives being hurt by an explosion will depend on the severity of their individual injuries and on the combined effect of all the injuries they suffer, the overall burden of injury."

COLONEL MAHONEY: Yes, sir, that's correct.
Q. "It will also depend on any pre-existing medical conditions a person has prior to injury, such as heart or lung disease, as this may influence how resilient they are to the effects of an explosion."
COLONEL MAHONEY: That's correct.
Q. So before we leave the question of management of blast injuries, and I ask Professor Bull to help us with the general approach that the panel took, is the use of oxygen something which may be relevant to help badly injured people?
COLONEL MAHONEY: Yes, it is.
Q. In what ways may that help?
COLONEL MAHONEY: Well, when I spoke about the physiology at the very beginning, I spoke about how we need oxygen delivered to our key cells, our key organs. When we talk about injury, and loss of blood and loss of lung function, we are losing that ability, we're losing the ability to carry the oxygen and, with lung injury, losing the ability to bring oxygen into the body.
So effectively, you have an individual who has less capacity to bring oxygen in from the air and less capacity to move it round the body. Supplementary oxygen is a means of trying to compensate for some of those losses by increasing the amount of oxygen in the

air the person is breathing and temporarily trying to compensate for the fact that they've lost some of the usual abilities to deliver oxygen to the body.
Q. We discussed blast lung earlier. If a person is experiencing blast lung, if that's the right way of putting it, is oxygen something that would be of assistance to them?
COLONEL MAHONEY: Yes, it would be, because they've lost some of the ability of the lung to take oxygen into the blood and into the body, so what we're trying to do by giving them supplementary oxygen is increase the amount of oxygen that's available to the remaining part of the lung, and trying to increase the amount of oxygen that they're delivering to the body.
Q. If there has been an explosion and someone has a catastrophic bleed, that is or is likely to be obvious to someone responding. How is a responder to identify that a victim has blast lung so as to know to give them oxygen?
COLONEL MAHONEY: They might not be able to early on. That's again one of the fundamental difficulties of the type of incident we're describing. Obvious external bleeding is relatively straightforward to recognise: you can see it, you can see what's in front of you.
Q. Yes.

COLONEL MAHONEY: With a lung injury, you may be relying on a number of more subtle signs, you may be relying on the rate the person's breathing at or how hard they're breathing, and if it's a conscious person, they may be saying, "I'm finding it difficult to breathe", or the rate may not be increased -- our experimental work at DSTL Porton Down has demonstrated this -- you may not get an increase in the rate of breathing. You may not get an obvious change in the way somebody's breathing. On one hand, it may look very obvious that someone is respiratory distressed, on the other hand it might not.
So I think it can be very, very difficult for an individual responding to an incident to say that's what is going on. The way we taught it within the military was: when you are thinking about proximity of an explosion and you're looking at other injuries, there are some injuries you may need to assume by virtue of the other injuries you've got, and then exclude them subsequently with your investigation.
Q. Thank you very much. That's all I wanted to ask you about the management of blast injuries.
Is there anything else you feel it's important for us to bear in mind, whilst recognising that you are returning to give evidence in due course?
COLONEL MAHONEY: I think the key thing is to say that the

important thing is basic, simple things done well. That's what saves people in incidents. It's good haemorrhage control, good airway management, it's recognition of holes in the chest and managing those appropriately. Good, basic first aid done well is what is required.
Q. That is certainly a most helpful summary, thank you.
Colonel, I'm going to turn from you now --
SIR JOHN SAUNDERS: Before you do that, you'll be aware that we have heard evidence of Brigadier Hodgetts' app.
COLONEL MAHONEY: Yes, sir, I'm a co-founder.
SIR JOHN SAUNDERS: Okay. Clearly, we are considering, and will consider, making recommendations relating to that because the public are the people who are on the scene, often first, and have the first opportunity to do something to help. Other people have suggested during the hearing that there is still some controversy about the use of tourniquets and how they should be used. I would be helped in due course -- not now, but in writing at some stage from you -- to know whether there is that controversy and to what it relates. I do not want to be in a position of making a recommendation which may be controversial and where there is still some investigation that needs to be done. So would you be good enough to do that for me?

COLONEL MAHONEY: Certainly, sir. I think we've addressed some of this in our subsequent reports as well, but we'd be very, very pleased to do that.
SIR JOHN SAUNDERS: Thank you very much.
MR GREANEY: Thank you very much.
I did say at the outset that we wouldn't be dealing with the arena attack and I repeat that we are not going to be dealing with any individual, but I believe it will help to provide context for what we're going to hear in chapter 12 if, first of all, professor you explain the methodology that was adopted by the panel and then if we turn to the colonel for an explanation of the classification of the general type of injuries that you applied in this case. Does that make sense as an approach?
PROFESSOR BULL: Yes.
Q. Could I ask you then to help us with the methodology that was adopted?
PROFESSOR BULL: Yes. I don't know if this is unusual, but this is what we were instructed and we were pleased to follow. So we met as a panel, all five of us, for a number of review meetings. We took a very considered approach to this where we first considered the post-mortem photographs. We then went through the post-mortem medical imaging together, and the medical

imaging was the CT scanning, and of course this allows the three dimensional visualisation of anatomical structures relevant to secondary blast injuries in particular, but also other things, and of course imaging of the secondary blast fragments.
We also conducted formal injury scoring. This is an important part of what we did because it allows us to compare to the literature and to other incident data that is known and out in the open literature.
Q. So it sounds like a very cold thing to do, applying a scoring to injuries, but this was something that you regarded it as critical to do so that you could compare and possibly contrast what was in the data within the literature?
PROFESSOR BULL: That's correct. I could go into greater detail, but I will very briefly say what that scoring is.
Q. Yes, please.
PROFESSOR BULL: The injuries are scored -- each individual injury is noted, it's recorded, it is given a score, a value, a numerical value of 1 to 6, with increasing severity. And then, according to the literature, these are then summed in some way to give us an idea of survivability. So for example, there may be one injury score of 4 of one part of the body, and the literature

might tell us that that would result in a chance of survival of 80%, perhaps.
Of course, that is a statistical approach and typically, when we are comparing with the literature, we have to compare with individual injuries rather than injuries where there have been -- blast injuries where there have been many, many injuries together. That makes this work quite difficult and I think we will end up discussing that in detail later on.
Q. I'm sure we will.
PROFESSOR BULL: But it was necessary to do so at this point.
We then --
SIR JOHN SAUNDERS: Is the scoring standard within the literature?
PROFESSOR BULL: It's not only standard, but those doing the scoring have to be accredited. I think it's worth noting that not all of the publications that include such scoring have accredited scorers who conducted that, so we have to go into the detail of these things sometimes.
MR GREANEY: The scoring that you undertook, as I've understood it, involved using something called the Association for the Advancement of Automotive Medicine Abbreviated Injury Scale or the AIS?

PROFESSOR BULL: That's correct.
Q. Which is an internationally recognised trauma severity scoring system?
PROFESSOR BULL: Yes. Very importantly, it doesn't look at and it does not score physiology, the responses that Colonel Peter was just referring to, it is about anatomical injury.
Q. And I think we shouldn't be distracted by the fact that it's an Association for the Advancement of Automotive Medicine that designed this scoring system in the first place, it applies to all trauma?
PROFESSOR BULL: There are many scoring systems, but the only one that is recognised internationally and widely is this one.
Q. So I just want to be clear about one thing -- again, we're not looking at individuals, but when you did look at individuals and the issue of survivability, did you simply look at the score and make your conclusion or was the exercise more sophisticated than that?
PROFESSOR BULL: Far more sophisticated and I will go through what we did beyond this point, which I think is important.
Q. Yes. I think it is too, so carry on.
PROFESSOR BULL: Following the injury scoring, we created injury maps. So these were schematics on which we

documented each one of the injuries. This was important for us as we then had to understand and analyse all the information we'd received prior to that, the post−mortem photographs and the CT scans, but also the information that we then looked at after that.

And at this point, I think it is safe to say that we took a pause and that we were able to identify individuals who had unsurvivable injuries, as we have previously discussed here today, at that point and we didn't need to go any further with any further detailed analysis for those for whom there was no doubt. And that was not everyone.

I think it's also worth noting that our approach was to be conservative, where we define conservative as erring on the side of survivability in all our assessments. We felt this was important as we were conducting not a statistical approach but a forensic approach for each individual. And we challenged one another and we challenged opinion as we went through this process.

But then we moved on, because clearly there were individuals for whom this was not definitive, and we reviewed witness statements and we −− even for all fatalities we reviewed witness statements to see if there were any inconsistencies and then we sought to

reconcile those.

When the videos became available, we reviewed all of these and we followed up at that point with additional work, where questions were arising from that video footage and from the witness statements.

The additional work included conducting full three−dimensional reconstructions of the medical imaging and conducting an analysis of that; comparing each one of those individuals that we were considering to the most equivalent blast injury survival data available −− and that is new information, and I will very briefly explain that here and we may refer to it later on.

So the military have a database, it is called JTTR, where they document all of the injuries and all of the fatalities and injury scoring can be conducted on those. So we have this wealth of data that allows us to investigate if there are individuals who have a similar or same injury constellation as those from the Manchester Arena bombing. And we're able to compare survivability of the cohort from the database with the individuals that we were considering and we did that.

Q. So people in that data who have the same or a similar injury profile to one of those who died in the arena attack?

PROFESSOR BULL: That's correct. And if we discuss those as

individuals, we would then have to say how fidelic comparison that was, because of course it is very difficult to find those with exactly the same injury constellation.

Q. Indeed, the same injury constellation may not necessarily be determinative: one may have to have regard, for example, to how fit and healthy the particular individual was as compared with the person one is analysing?

PROFESSOR BULL: And not just fit and healthy. It's something that has not yet been mentioned, but clearly there are differences in physiological response and there's difference in anatomy between those who are young and those who are older.

Q. Absolutely, which is something we will get to but not today.

SIR JOHN SAUNDERS: Is that an international or national database?

PROFESSOR BULL: It is ours. There are equivalent databases −− the US have equivalent databases.

MR GREANEY: When you say ours, you're talking about the centre?

PROFESSOR BULL: No, UK military.

Q. Is there anything else that it is important that we should understand about the methodology that the panel

adopted?

PROFESSOR BULL: Just one additional piece of work that was conducted where relevant was analysis of the physiological aspects and that was analysis of the blast injury modelling work that was conducted at DSTL and we incorporated that where necessary for individuals.

Q. Thank you very much.

As you'll appreciate, it was important that we should understand your methodology because it was the methodology that was applied to each of the 22 victims of the arena attack. There will come a stage when you return later, when it will be necessary for me, and I have no doubt others, to explore some aspects of your methodology in relation to at least one of those 22. I just say that so that everyone should understand that we'll need it look at this again in due course, as you'll appreciate.

SIR JOHN SAUNDERS: I don't want to consider it, but has this exercise ever been carried out before in these ways, these terms?

PROFESSOR BULL: Similarly, but not necessarily exactly the same. So for the Birmingham pub bombing, we conducted a very similar analysis, but we didn't have all the same information.

SIR JOHN SAUNDERS: This is something you did recently

presumably?
PROFESSOR BULL: We did it for the inquests.
SIR JOHN SAUNDERS: So a long time after the event?
PROFESSOR BULL: That's correct.
SIR JOHN SAUNDERS: Does that matter? You don't need to answer that in detail, but does it make a difference?
PROFESSOR BULL: If the records are available, it doesn't matter, but some records were not available so we were not able to do some of the things that we were able to do now. And of course the medical training may well have been different at that time. So we're also then referring to Colonel Peter's evidence and how the medical interventions may have been different.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: Was this kind of work also undertaken in relation to the 7/7 attacks?
PROFESSOR BULL: That's also correct, but certain information wasn't available. I wasn't involved in that, Colonel Peter was, but I was involved in the Birmingham one. For example, post-mortem CTs were not available in that --
SIR JOHN SAUNDERS: Because of the length of time. But for 7/7, exactly the same procedure was gone through?
COLONEL MAHONEY: Very similar, sir. In 7/7, there was very different availability of imaging, we didn't have the CT

post-mortem imaging, and there was very limited photography on the victims. So we had to do, with the aid of Porton Down, environmental modelling, looking at the blast environments at a millisecond by millisecond within the carriages and within the bus. So a similar approach, but the nature of the incident and the nature of available information meant that we had to finesse our approach.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: Have I understood correctly, you were in a better position in this case than you were in relation to 7/7 to reach your conclusions?
COLONEL MAHONEY: Yes, that's correct.
Q. And were you in the same or a better position as compared with Birmingham?
PROFESSOR BULL: Yes.
COLONEL MAHONEY: Far better.
Q. Professor, is there anything else it's important that we should know about methodology, bearing in mind we're just receiving your general evidence at this stage, or can I turn to the colonel to help us with the definition of certain terms?
PROFESSOR BULL: Nothing further.
SIR JOHN SAUNDERS: Can we be reminded of when Birmingham was? I was in the city at the time.

MR GREANEY: 1974, sir.
The terms, colonel, that I'm going to ask you to help us are important terms because they are the terms that you use to define what had happened to the 22 in this case.
COLONEL MAHONEY: That's correct.
Q. The first term I'm going to ask you to help us to understand is unsurvivable. I'm at page 20 of your report.
COLONEL MAHONEY: We were aware from the open access reports in the media that a lot of people had survived the bombing and so taking the approach that Professor Bull has described, we wanted to be objective but we were also trying to find reasons and asking ourselves: could this person have survived? Is there something that could have been done differently to allow this person to survive? Is there something we would advocate which would allow this individual to survive? So we were going in very much thinking and looking for reasons for individuals to survive.
We had a number of terms to classify the injuries and one of the terms was "unsurvivable". Taking the approach where we were saying, is there a reason for this person to survive, if we said that we believed somebody had unsurvivable injuries, it meant that we

felt the injuries were so severe that even if the most comprehensive and advanced medical treatment was initiated immediately after injury, we believe that survival was impossible.
Q. Were you making that judgement by reference to the most comprehensive and advanced medical treatment that was available as of 22 May 2017?
COLONEL MAHONEY: Yes.
Q. The next term that you used is "unlikely to be survivable"; what should we understand that to mean?
COLONEL MAHONEY: These are individuals whose injuries were so severe that even if that same advanced and comprehensive medical treatment was initiated immediately after injury, we would not expect that person to survive, but at that point we could not say survival was impossible.
Q. The final term "potentially survivable".
COLONEL MAHONEY: This is where individuals had suffered injuries that could prove fatal, but we had personal experience of looking after casualties who had survived such injuries. So survival was not guaranteed but we believed that survival was -- we were certainly aware of individuals who had survived such injuries with appropriate treatment.
SIR JOHN SAUNDERS: That had to be the personal experience

of one of you?
COLONEL MAHONEY: It could be, sir, yes.
SIR JOHN SAUNDERS: Could be, but did it have to be? For example, if there are examples of people in the literature ——
COLONEL MAHONEY: In the literature, personal experience, our collective military experience, the JTTR as an example.
SIR JOHN SAUNDERS: I just wanted to understand what you meant by, "We had experience of people surviving".
COLONEL MAHONEY: We had experience both personally and institutionally. What we didn't want to do was be guided by anecdote, but if an individual said, "Hang on, stop, I have managed this injury in this environment", then we'd say, "Okay we need to pressure test that and understand why you believe that", and then reach back into the literature and make sure we had the appropriate evidence to defend that.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: So Brigadier Hodgetts, have you had a chance to see or to at least read the transcript of the evidence of Brigadier Hodgetts?
COLONEL MAHONEY: Yes.
Q. He describes a group that was well recognised and I think he called them unexpected survivors.

COLONEL MAHONEY: He did, yes.
Q. Is that the sort of material that you had regard to so long as it was more than merely anecdotal?
COLONEL MAHONEY: Yes, that was part of it. In addition we had JTTR, the Joint Trauma Registry Records, that we could reach into and we had the open access literature, and we had our own experiences as well.
Q. I have said it many times but I know this is an issue that we will need to come back to in due course.
Before I conclude my questions and turn to others, is there any other issue that relates to the topic you've just been dealing with that we ought to know about, for example the difference in terms of survivability that you have encountered as between blast injuries compared with other forms of trauma?
COLONEL MAHONEY: I think what's key to say at this stage is just how severe injuries from explosions are and can be. Certainly when I was actively doing pre—hospital care, I'd regularly attend road accidents and regularly attend industrial accidents. You can have a very unpleasant and very mutilating road accident, and I'm not in any way dismissing that, but the sheer ferocity of an explosion and the complexity of the injuries that you can get from an explosion are almost in a different league of their own. A league of their own.

SIR JOHN SAUNDERS: I'm not quite sure whether this is a sensible question or not, so if it's not, please don't answer it. When you're describing how you approach survivability, obviously from the point of view of the lessons that can be learned from what happened at Manchester, a conservative view, ie you err on the side of survivability and what can be done is helpful from the point off view of trying to think: was there anything at all which could have been done which we can learn from in the future?
COLONEL MAHONEY: Yes.
SIR JOHN SAUNDERS: That's one way of looking at it. On the other hand, you can look at it and say, well, if we decide they were survivable, that means we may be saying that someone could have done something which they didn't do, which is obviously something which one is not keen to do necessarily. Do either of those two play in and if you think that question is not helpful, then please don't answer it.
COLONEL MAHONEY: Sir, I think it's an entirely fair question. We were very conscious of what the inquiry was asking us to do, that our brief was to look at survivability, and by definition if you're looking at survivability, you have to ask uncomfortable questions and say, "Had this action been taken, would the outcome

have been different", or, "If this action hadn't been taken, would the outcome have been different?"
And again, we felt we owe that to the inquiry as our duty to be able to give an answer for those uncomfortable questions, and I suspect we'll be addressing those when we look at individuals.
SIR JOHN SAUNDERS: Thank you.
MR GREANEY: It most certainly was not, if it's for me to say, anything but a sensible question. I know that is an issue that Mr Weatherby is concerned to explore, although I doubt today. Can I say that I am satisfied that once we have looked at the individual cases, we will know where on that spectrum we are.
SIR JOHN SAUNDERS: Thank you very much.
MR GREANEY: So the two of you, if I may say so, are very experienced experts, including at giving evidence. Bearing in mind that what I'm seeking from you at this stage is your overview evidence, is there anything else that either of you consider that we need to be informed about before we embark upon chapter 12?
PROFESSOR BULL: Not from me.
COLONEL MAHONEY: Not from me, no.
MR GREANEY: Sir, is there anything you would like to ask before I ask Mr Weatherby in the first instance and then Mr Cooper whether they have questions?

SIR JOHN SAUNDERS: No, thank you.
MR GREANEY: Mr Weatherby, do you have any questions at this stage, bearing in mind the witnesses will be returning?
MR WEATHERBY: Nothing at all at the moment, thank you very much.
MR GREANEY: I know Mr Cooper does have a few questions.

Questions from MR COOPER

MR COOPER: I'll address you first if I can, Professor Bull. As you know I represent a number of the families and I'm aware that we're at the general phase at the moment of questioning of both of you and we'll acutely adhere to that.

You have spoken about fragments in your earlier evidence —— I address this to you, Professor Bull. My question is this on a general basis: do nuts, for instance, and other items like that, packed into a device, as a primary fragment, react in a different way to, say, simply bomb debris such as the packaging? Do you understand what I'm getting at here?
PROFESSOR BULL: Yes.
Q. You've described the effect of the debris, the packaging. We know that, generally, bombs can be packed with dangerous items such as nuts. Do they react in a different way after an explosion to general debris?
PROFESSOR BULL: There are multiple things going on. The

first is how they are energised, and if they are very close to the seat of the explosion, ie part of the device, then they will be energised more and they will receive more of the energy and therefore they will have greater kinetic energy as they move. They will go faster and they will tumble faster. If they are further away, then of course they will have lower energy.

So typically that would be a way of understanding the difference between primary and secondary fragments, but not necessarily. So that would be on the continuum there would generally be greater energy for those materials/fragments that are packed as part of the device.

Secondly, the shape and the mass is obviously —— the weight is obviously very important because the shape itself can potentially be more detrimental, and the aerodynamics of that shape will cause it to move through the air in different ways.

So yes, they're absolutely critical and there is much research that is being conducted on that, but suffice to say that there is a difference between the different types of fragments.
Q. Thank you.
SIR JOHN SAUNDERS: I think Mr Cooper's question was predicated on —— we're talking about either the

packaging or the nuts and bolts inside. I don't think we were talking about other things that can be swept up as you describe.
PROFESSOR BULL: The packaging is extremely different, clearly, in this case and other cases, from the nuts.
SIR JOHN SAUNDERS: Because of what they are made of?
PROFESSOR BULL: Because of what they're made of and therefore the kinetic energy that they have —— one items will have a much lower mass, much lower weight and so it will have much less energy.
SIR JOHN SAUNDERS: But could be sharper, for example?
PROFESSOR BULL: Yes.
MR COOPER: Is there a range that can be determined for fragments that are affected by detonation, how far they will travel? Is that determined, for instance, logically on the force of the explosion or are there other determinants as to how far these dangerous materials travel?
SIR JOHN SAUNDERS: Can we be quite careful about not giving information at this stage?
MR COOPER: Let me explain why I'm asking the question.
SIR JOHN SAUNDERS: You'll understand my concern.
MR COOPER: Absolutely. By explaining why I'm asking the question, there may be a way round answering it. Without going into the particularity of the evidence at

this stage, some people closer to the detonation received less injuries than those that were a distance away from the explosion. And without going into the particularity of the individuals, just asking about the physics of it, how can it be perhaps —— and I know this is of concern to some members of families —— that someone closer perhaps to detonation receives less injuries than someone further away from detonation?
PROFESSOR BULL: I'm glad to clarify this. First, the explosive itself may not be a very consistent explosive. It may detonate in a way that is not ideal. So what that means, and that generally is not by design, these things can just happen like that. So what would happen is that the pressure and then the blast wind that follows that pressure is not consistent around the sphere. So what you would have is a sphere of pressure and of blast wind coming, which has sort of peaks and troughs, if one may explain it like that, and those peaks and troughs would carry the debris or the fragments in different directions with different energy. That's the first point.

And that would provide one reason for why we saw that. I think another reason is that, clearly, if there are objects or individuals in the way, then clearly the line of sight question would address that as well.

I think, based on our expertise and on modelling that has been done previously, nothing that we saw was inconsistent with that.
Q. Thank you. On recommendations, we know the City Room is not considered a closed environment, and therefore will cause(?) an open environment. Are there any recommendations either of you can think of that may potentially protect to some degree people from detonation? I'll start from an extreme example, whether there should be partitions in open environments like that, that may act as screens or protections to close the environment? And might in the future open environments like the City Room be designed in such a way to restrict that openness and therefore to provide a better degree of safety?
PROFESSOR BULL: We believe there are potential recommendations, but I'm concerned about giving them in this forum.
Q. Then please don't and I wouldn't ask you to here.
MR GREANEY: I think that we can say the work has been done and continues to assist those responsible for buildings in this regard. Is that fair way of putting it?
PROFESSOR BULL: That's correct.
MR GREANEY: I think we probably shouldn't go any further than that.

MR COOPER: I won't pry. Will the chair be made aware, might I ask, of that work?
MR GREANEY: Yes.
MR COOPER: That's all I ask. Thank you.
May I move on to another matter, I think it's still directed at you, Professor Bull, if I may, and this is predicated on experiences that individuals had on this tragic night. I ask it generally. Observations are made about the noise of the explosion and the detonation. Obviously, we can be bland and use lay terms, "We think we know what an explosion sounds like", but are there any nuances or particularities on how the noise is produced from an explosion so as to perhaps help those that heard it understand what was going on?
PROFESSOR BULL: I am unaware of detailed literature on this, so I do not have specific knowledge and expertise in that area and I don't know if it is available anywhere. I apologise for that.
Q. Colonel, I don't know whether there's anything on that basis you can add, but if there is no learning on it I wouldn't press you unless there's anything you want to contribute.
COLONEL MAHONEY: I don't think I can answer your question the way you would like. Certainly, again, from personal experience, it's really depended on the distance you've

been to an explosion. Being in a room with one going on outside, you get a shaking and a loud bang. For more slightly more distant ones and you're outside, you might get a flash, you might get a bit of a push, you probably won't get as much noise if you're further away.
It really depends on the environment you're in and whether it's a rocket, a car bomb, a person-borne bomb, a mortar. It really depends on where you find yourself and what's going on.
Q. Another of the experiences those we represent had generally was the blinding flash, the momentary blinding light, as it were, which caused debilitation. Again, is there anything physically you can explain as to what was going on there so at least this can be demystified for those who experienced it?
PROFESSOR BULL: It's absolutely expected in such type of explosions that you'd get a flash like that. It's absolutely common and almost everyone will have experienced that.
SIR JOHN SAUNDERS: And it is caused by?
PROFESSOR BULL: It's caused by the chemical reaction. You get this flash -- this extreme shock wave and extreme burning that happens almost instantaneously, and you have the shock wave going through the product as the device is ignited.

SIR JOHN SAUNDERS: Thank you.
MR COOPER: Again, finally on this topic, a number of people experienced severe heat, some more than others, a severe feeling of burning as far as they were concerned. You have touched on it in your report. Is there anything else either of you can add again as to the physical mechanics of that as far as the bomb is concerned, what's causing that?
PROFESSOR BULL: Whenever molecules move quickly, then heat is produced, and there are lots of molecules moving very quickly due to the pressure wave and the blast wind that follows that -- and of course there are actually things that have been detonated, so there is fire present as well.
Q. That's helpful. You understand the reason I'm asking these questions on behalf of those we represent is simply to demystify what went on, which for some might be helpful.
PROFESSOR BULL: I'm very pleased to answer your questions.
Q. On another aspect, if I can deal with medical aspects -- and perhaps colonel, I should turn to you so far as that's concerned.
You say at your paragraph 2.3.2 in your report that: "Damage to blood vessels can cause early death but there may be sufficient time for medical interventions

to save life."

I'll be asking you other questions in due course on this, there's no secret about it, I represent John Atkinson and obviously at a later stage we will be asking you some particular questions about the matter. But I'm just talking about your general observation now, which was touched upon by CTI:

"Damage to blood vessels can cause early death but there may be sufficient time for medical interventions to save life."

I presume from that you mean direct pressure, the use of a tourniquet, and elevation, I think you said in your evidence today?

COLONEL MAHONEY: Yes, if we're talking about an external bleed, say with a limb injury, then all those factors, pressure, elevation, tourniquet, may be appropriate and may be required. But equally, you could have internal damage to a blood vessel, internal damage to a big blood vessel in the chest, and somebody could be bleeding out very rapidly but you couldn't actually do anything about it in the context of the incident because you can't see it and you can't reach it, you're looking at surgical intervention.

SIR JOHN SAUNDERS: So internal bleeding, you simply can't do anything about?

COLONEL MAHONEY: Internal bleeding means you're looking at surgery ——

SIR JOHN SAUNDERS: Stemming the bleeding? If you know it's occurring in a particular place internally.

COLONEL MAHONEY: If you can see something —— I will answer the question, but if you can see something externally, say bleeding from a limb that is coming out, you know to put pressure, elevate and possibly a tourniquet. If you have bleeding in the chest or the abdomen, then you may know it's taking place, but short of actually reaching in to stop it, you're fairly constrained.

SIR JOHN SAUNDERS: So external pressure will not stop internal bleeding?

COLONEL MAHONEY: Certainly in something like a chest injury, no, it won't. There is research and there has been US military research looking at approaches to abdominal bleeding, whether there are devices that could provide external pressure to address bleeding within particular parts of the abdomen. That's really fairly new and innovative and it's not in —— certainly not in routine pre—hospital care, sir.

SIR JOHN SAUNDERS: Thank you.

MR COOPER: You again, colonel, referred to this in your evidence earlier on this morning, that certain injuries are amenable to the application of a tourniquet.

COLONEL MAHONEY: Correct.

Q. You weren't asked as to what those injuries were, so let me ask: what are these injuries that are amenable to the application of a tourniquet?

COLONEL MAHONEY: So we're considering limb injuries and limb injuries where you have —— where you're aware of where the blood vessel is, aware of where the bone is, and you can apply a tourniquet and effectively pressurise a vessel against a bone and inhibit the flow. It really depends on where you are in a limb. Does that answer the question correctly for you?

Q. It does. It's a matter for the chair of course, but certainly so far as I'm concerned.

Again on the subject of injuries concerning loss of blood, it's a general question for now. In those sort of injuries, is how someone is transported following that injury a critical aspect to consider as well? By that, I mean stretchers or otherwise.

COLONEL MAHONEY: So if we have a situation where bleeding has been controlled by a tourniquet, for example, or pressure or elevation, and you no longer have bleeding, then the key consideration is getting them to appropriate help, whether they were put on the stretcher or maybe if they're stable enough, you might move them in a chair or sometimes you might walk somebody out. It

really depends on their individual condition.

Where you have internal injuries, where you believe there's still bleeding ongoing, you really want to handle people very, very gently because you don't want to do anything to make the bleeding worse. So under those circumstances, if you have the ability to put somebody on a stretcher and take them out in a relatively controlled fashion, that's what you do. But in threat environments, particularly in the military environment, we frequently haven't had that luxury, so we've had to accept a less—than—ideal evacuation to take people out of direct threat and then try to address the consequences subsequently.

Q. As you'll anticipate, I'll be returning to that topic in a little more detail later, but that's all I ask for now.

COLONEL MAHONEY: Sure, I understand.

Q. How important in terms of the injuries you've spoken of, particularly blood loss injuries, how important is it to maintain the consciousness of a victim?

COLONEL MAHONEY: I know people talk about it, but the key thing is stopping the bleeding —— recognising the injury, stopping the bleeding and getting them to care. If someone's conscious, you hope they are maintaining their airway and you hope that they are at least

demonstrating they're cerebrating.

When I have looked after casualties, I haven't tried to maintain their consciousness. If I've seen them slipping into unconsciousness, I have taken that as an indication of severity and something going on I would like to deal with. I'm not trying to sound callous, but I'm not that concerned about talking to them to maintain their conscious level; I'm more concerned about what is that decreasing conscious level telling me about their ongoing injury.

Q. That's probably debunked a lot of myths we see in the movies and such, where people are being kept awake and talking, which seems to be an utter myth medically as far as you're concerned.

COLONEL MAHONEY: Yes.

Q. Just one final topic now in terms of blast and ballistic mechanisms. You say in your paragraph 5.10 ——

SIR JOHN SAUNDERS: Sorry. You described it as a myth of keeping people there and we all see this all the time of people trying to keep people conscious to stop them slipping away.

COLONEL MAHONEY: On television dramas, yes.

SIR JOHN SAUNDERS: If that is a misconception, is it a misconception that should be rectified? Because it may be that if you're trying to keep someone awake and

conscious, you're not doing something else which you might be doing. You would say you would be concentrating on the bleeding rather than maybe keeping someone conscious.

COLONEL MAHONEY: For me, it's more important to say why am I seeing a change, so I need to be looking for something rather than I need to be talking to this person.

SIR JOHN SAUNDERS: Okay.

COLONEL MAHONEY: I'm not sure if I've answered that correctly for you.

SIR JOHN SAUNDERS: You have. I understand what you're saying. I was trying to conceive of whether —— if it's certainly a misconception, it will be a misconception that I and most people, I suspect, here would have, whether it's a misconception which needs to be put right.

COLONEL MAHONEY: Other people may disagree with me, but certainly my approach ——

SIR JOHN SAUNDERS: That's an important thing to know, whether it is a matter for debate, as it were. Okay.

MR COOPER: Just this then, it's your paragraph 5.10 —— I'm not sure whether this is for Professor Bull or you, colonel, but either of you of course will pitch in:

"Blast and ballistic mechanisms are different due to

the usual injury mechanisms encountered in UK civilian NHS practice [as read]."

But is that really the case? I'm asking this question as to whether domestic NHS practice should be alert to these problems, for instance these explosions can happen, for instance, as a result of a house fire or a factory fire or indeed, very sadly, a number of health and safety deaths. One only reads today of somebody dying because of an explosive large beer keg that they opened in the wrong way and the keg exploded. Should it be that a civilian NHS practice should be far more alert and far more informed and far more trained to deal with those explosions, whether or not they're from a sinister source?

COLONEL MAHONEY: If I could refer, please, to paragraph 5.11, where we have described taking our military experience and binding that into current NHS protocols. I absolutely agree that you do get domestic explosive events and industrial explosive events, which present to hospital or present to the emergency services and subsequently to hospital and are generally dealt with extremely well by the NHS.

I think the key thing about the arena and other terrorist events is that you are dealing with a device, an event that has presented a complex constellation of

injuries with frequently a significant number of casualties and has invoked an understandable concern about other likely threat. So you are managing a significantly difficult environment, a number of people, and you might be presenting individuals to an NHS crew, an ambulance crew or a hospital who haven't seen those injuries before.

This is the reason why the military were involved in working with our NHS colleagues to develop the guidelines discussed in 5.11. What these guidelines do is give a very readily accessible means of seeing blast injury, ballistic injury and blade injury so that if you know you're on duty and people with these injuries are coming to you in hospital, you can quickly refer to the guidelines, understand what you're likely to face, and indeed reassure yourself that most of your knowledge is entirely applicable to managing that person.

Q. My last question following on from that: what's your view on the adequacy and the level of consistent training that is given to the NHS in relation to the matters you have just referred to, that is military perspectives upon the consequences of, for instance, terrorist activity and bomb detonation? Is there an increase in training that is necessary? Is all this training going to the rank and file in the

Ambulance Service or is it in a tiered way?
SIR JOHN SAUNDERS: Quite a big topic. If you don't feel able to deal with it at this stage, by all means take time to think about it.
COLONEL MAHONEY: It is a big topic and to have an appropriate and accurate answer, you would perhaps need to speak to individual NHS trusts and ambulance trusts to understand what they're doing for their people. But I think it's fair to say that there are some very comprehensive courses that have been going for a number of years addressing major incident management and things, like in Birmingham, the trauma course about teaching NHS people how to manage these types of injuries has been running for a number of years.
There's plenty of training out there, but as to how it's being addressed nationally, I'm the wrong person to answer that.
MR COOPER: Was there training available pre-2017, do you know?
COLONEL MAHONEY: The major incident management training, MIMMS, also something developed by was Colonel, now General Hodgetts, has been available for a number of years and certainly pre-dated 2017. A number of the courses have been refined since 2017. I think people have definitely learned from the experience of the arena

bombing.
MR COOPER: I'm grateful, sir, thank you. I have no further questions.
SIR JOHN SAUNDERS: Thank you very much, Mr Cooper.
Further questions from MR GREANEY
MR GREANEY: Just one thing. The guidelines to which you drew Mr Cooper's attention referred to a paragraph 5.11 of your report are dated 2018 is that correct?
COLONEL MAHONEY: That's correct.
Q. They post-date the arena attack?
COLONEL MAHONEY: They post-date the arena attack and the requirement for them was influenced by the arena attack and by the other attacks that took place in 2017.
Q. Which gives rise to the question of whether, as of May 2017, that which had been learned on the battlefields was sufficiently understood within civilian NHS practice. Again, maybe a big topic.
COLONEL MAHONEY: I think it's a big topic and I don't think it's correct for me to comment on. At the time I was working in Birmingham in the Royal Centre for Defence Medicine, where we were working hand-in-glove with our civilian colleagues.
Q. I understand.
COLONEL MAHONEY: So if you take what Birmingham knew, where we were constantly bringing this material back and

looking after blast and ballistic casualties, both from military environments and other environments, and I was certainly very, very confident with how the Queen Elizabeth Birmingham were managing such incidents, but I cannot say what is happening in other trusts.
Q. So your experience within Birmingham may or may not have been typical, you can't comment. But what you can say is that, as we stand here today, the learning from the battlefields is well understood within the NHS?
COLONEL MAHONEY: I think what we can say is that there is certainly -- there's been attempts to provide that learning with things such as the 2018 guidelines and I believe there's a greater understanding within ambulance services. Certainly when I've spoken to ambulance crews, their understanding of blast and ballistic injuries has been good and their understanding of tourniquets has been good. How that permeates to every ambulance trust or every hospital trust, I really can't say.
SIR JOHN SAUNDERS: Birmingham is slightly different, isn't it, because isn't that the centre where most people injured abroad in the military are brought for further treatment?
COLONEL MAHONEY: That's correct, which is why -- that's where I was working up until early 2020 when I was still

serving in the regular army. So my experience was based around that, either on deployment or working back in Birmingham. So it would be unfair of me to draw conclusions from that because that's an unusual environment.
SIR JOHN SAUNDERS: Thank you.
Further questions from MR COOPER
MR COOPER: Could you indulge me with one question. It may or may not be a help.
SIR JOHN SAUNDERS: You can ask if it it's going to be a help, Mr Cooper.
MR COOPER: Is what you say of the provision of information to the National Health Service -- do you have a similar communication with the Fire Service?
COLONEL MAHONEY: Me as an individual, I don't.
Q. I don't mean you personally, I mean the general chain of learning that you explained very helpfully that's provided to the Ambulance Service, is there a similar provision nationally to the Fire Service?
COLONEL MAHONEY: I really would need that question addressed to the Fire Service. It is not something I have personally been involved with.
SIR JOHN SAUNDERS: It's a sensible question and we will get it answered. Thank you, Mr Cooper.
MR GREANEY: Sir, do you have any questions?

SIR JOHN SAUNDERS: No, thank you.
MR GREANEY: That's taken a little longer than I expected. I know that Ms Cartwright is very keen that she make her remarks about process and procedure at this stage so that the evidence is able to start at 1.30 sharp and it's not interrupted. So could I suggest a break until 12.20, please?
SIR JOHN SAUNDERS: Thank you both very much. We'll be seeing you again.
(12.12 pm)
(A short break)
(12.22 pm)
MS CARTWRIGHT: In the opening statement to the inquiry on 7 September 2020, Mr Paul Greaney Queen's Counsel detailed that:
"In chapter 12 we will explore the experience of each deceased victim. The cause of death of each person will be investigated during this chapter and this chapter will also provide an opportunity to remind ourselves, and indeed the world at large, of the pen portrait evidence heard in chapter 4.
"We should acknowledge that during and throughout chapter 12 we will be dealing with matters that are undoubtedly sensitive and likely to be distressing for many, certainly the bereaved families and the witnesses

who will be called. As always, we will do what we can to reduce the distress, although we recognise that we can never be completely successful. However, we are able to provide reassurance at the beginning of chapter 12 that we will not be showing any CCTV or body-worn video footage or still images.
"As is well-known, our inquiry process began as 22 inquests requiring findings as to how and in what circumstances each of the 22 who died came by their deaths and the medical cause of death. These aspects are addressed by and respectful attention given to them in the inquiry's terms of reference 6 and 7 and form the focus of chapter 12."
Paragraphs 6 and 7 of the terms of reference include:
"6. The experiences of each person who died, including their travel to the arena, the locations they visited, who they were with, their movements at and around the arena."
And in paragraph 7:
"The immediate cause and mechanism of each death, including:
"(i) The mechanism and cause of death;
"(ii) Exactly when and where each person died (to the extent that this is possible to ascertain);

"(iii) Survivability, including whether any inadequacies in the emergency response contributed to individual deaths and/or whether any of the deaths could have been prevented."
Turning next to preparations for chapter 12, yesterday afternoon Mr Greaney Queen's Counsel detailed that I would explain the process by which the chapter 12 evidence has been gathered and the procedure that will be adopted during chapter 12 itself and an indication of the intended timetable.
The inquiry legal team acknowledge in these introductory remarks the extensive work that has been undertaken for chapter 12 by Operation Manteline and the team supervised by Detective Superintendent Theresa Lamb and Detective Inspector Mike Russell. This has included many hundreds of hours analysing the footage from 90 CCTV cameras, footage from 52 body-worn videos and mobile phones, which has enabled to be extracted from this evidence a clear timetable for each of those who died and details: firstly, their arrival at the arena for the concert; (2) the time when they entered the City Room shortly before the bomb was detonated; (3) their location in the City Room at the time of the detonation; and finally, an analysis from after the detonation at 22.31 and what happened to each of those

who died and the details of those who interacted with and assisted them thereafter.
The work of the Operation Manteline team in preparation for chapter 12 has been invaluable and the inquiry legal team records and expresses its sincere thanks to all of those in the Operation Manteline team who have been involved in this sensitive and most difficult work.
This work has resulted in 22 detailed, chronological sequence of events for each of those who died, with stills extracted from the CCTV body-worn video and, where appropriate, mobile phone footage.
In addition to the 22 sequence of events for each of those who died, a further 77 individual sequence of events for witnesses have also been created by the Manteline team. The focus of these sequence of events has been the witnesses' interactions with each of those who died.
Using the individual witnesses' sequence of events, a comparison exercise has been undertaken of the witness statements earlier provided to ensure any necessary matters not addressed by the witness, when compared with what is shown on the CCTV and body-worn video, was addressed, with requests for additional statements being made by the inquiry legal team.

Operation Manteline have interviewed and taken additional statements from approximately 45 witnesses in preparation for chapter 12. These additional witness statements will enable the questioning of the witnesses to be called in chapter 12 to be necessarily focused.

The inquiry legal team is grateful also to the Resilience Hub for its assistance in supporting witnesses with the statement-taking process and for the overarching support given and to be provided in chapter 12.

The work for chapter 12 has included the inquiry legal team preparing detailed evidence notes for each of those who died, which were provided to each of the representatives for the families. The purpose of those notes was to assist the families to understand all of the available evidence, about what happened to their loved ones, and to identify which parts of that evidence should fall to be adduced in evidence during the chapter 12 hearings. Those notes assisted the discussions with the family teams about what evidence should be heard, how, and from whom in chapter 12.

As can well be appreciated and understood, some families wished far less detail to be adduced in the final chapter 12 summaries of evidence; other families wished for more detail to be heard.

The inquiry legal team is grateful to all of the families and their legal representatives for their cooperation with the process of preparations for chapter 12. As a result of these discussions, for 15 of those who died the evidence summary will be read as agreed with the family and no live witness evidence called. For seven of those who died, in addition to the reading of the evidence summary, live evidence will be called.

The evidence summaries to be read in chapter 12 at the hearings each consist of, first, a reading of the summary of the pen portrait evidence that has been received in chapter 4, whilst a photograph of the person who died is displayed in the hearing room.

The families have chosen who should read this pen portrait summary. This will then be followed by a reading of a summary of the evidence that details the matters falling within the inquiry terms of reference 6 and 7.

Detective Inspector Mike Russell will assist counsel to the inquiry with the reading of the summaries of evidence in chapter 12. Detective Inspector Russell will read the evidence as extracted from the evidence sequence of events prepared by his team. Rather than adducing this evidence in the format of questions and

answers, Detective Inspector Russell will simply read those extracts from the sequence of events for each of those who died where the evidence appears in the summary.

The remainder of the evidence summary, from extracts of witness statements and other sources, will be read by counsel to the inquiry. This will include reading the medical cause of death as given by the pathologist following post-mortem examination, expressed using the formulation of medical causes of death used at inquests, namely 1A, the condition immediately causing death.

The summaries to be read, save for that of Saffie-Rose Roussos's will give a summary of the blast wave panel's conclusion on survivability and the conclusion of Dr Lumb and Professor Crane following their pathological review.

This afternoon, the summaries for Angelika and Marcin Klis and Courtney Boyle will be read.

Tomorrow, the summaries for Philip Tron, Olivia Campbell-Hardy, Michelle Kiss and Jane Tweddle will be read.

On Thursday, the summaries for Lisa Lees, Alison Howe, Wendy Fawell and Nell Jones will be read.

On Monday, 27 September, the chapter 12 summary for Megan Hurley will be read as well as brief live evidence

from five witnesses. In the afternoon of 27 September, the summaries for Eilidh MacLeod and Sorrell Leczkowski will be read.

On Tuesday, 28 September, the chapter 12 summary for Kelly Brewster will be read as well as brief live evidence from six witnesses. In the afternoon of 28 September, the summaries for Liam Curry and Chloe Rutherford will be read.

On Wednesday of next week, the chapter 12 summary for Georgina Callander will be read as well as brief live evidence from nine witnesses.

On Thursday 30 September, the chapter 12 summary for Martyn Hett will be read as well as brief live evidence from witnesses. In the afternoon of 30 September, the summary for Elaine McIver will be read as well as brief live evidence from four witnesses.

In the week commencing 4 October 2021, the factual evidence for Saffie-Rose Roussos will be heard on 4 and 5 October. The factual evidence for John Atkinson will be called on 6 and 7 October, and will continue on Monday 11 October.

As detailed by Mr Greaney yesterday when making his introductory remarks for chapters 11 and 12, he said this:

"The inquiry will consider the issue of

survivability in the case of each of those who died. This is, of course, an important question in its own right and, moreover, will be capable of bearing on the consequences of any failure in the adequacy and/or effectiveness of the emergency response."

On 12 October, medical expert evidence will be called to confirm the conclusions of the blast wave experts and the pathologists, Drs Crane and Lumb, of all of those who died save, for good reasons known to the core participants, Saffie-Rose Roussos.

As there is an issue of survivability for both Saffie-Rose Roussos and John Atkinson, the medical and expert evidence will have to be examined in detail and with care to enable you, the chairman, in due course to determine the issue of survivability. This will take place for John Atkinson by way of the evidence, the medical evidence, on 12 October, and for Saffie-Rose Roussos on 1 to 3 December of this year.

Sir, we will start the chapter 12 evidence summary for Marcin and Angelika Klis at 1.30 this afternoon, and could I ask that we adjourn now until that time.

SIR JOHN SAUNDERS: I am also very grateful for the work that the police officers have done in assisting with this process. I am also, as I said yesterday, grateful to the core participants for the families for their

assistance, but can I also say, Ms Cartwright, you have taken the lead on this as far as the inquiry is concerned and you have done an enormous amount of work, along with other members of the team who have helped you, and I'm very grateful for that.

I want to say one thing: when we had the pen portraits as part of chapter 4, the importance of that was to ensure that everyone was aware we were dealing with 22 very individual and very special people. Inevitably, since then, we have tended to deal with 22 all together, and it is good that we are being reminded again that we are dealing very much with 22 individuals, and I may say that I'm reminded of that every day as I come into the hearing when I look at the portraits which are behind me. But they have never been out of our minds as 22 individuals, even though inevitably the evidence was the same for all of them. Thank you.

MS CARTWRIGHT: Thank you, sir.

SIR JOHN SAUNDERS: 1.30.

(12.38 pm)

(The lunch adjournment)

(1.30 pm)

Evidence summary for ANGELIKA KLIS and MARCIN KLIS

MS CARTWRIGHT: Good afternoon, sir.

This is the chapter 12 evidence summary for Angelika

and Marcin Klis. Please can their photograph be displayed?

Please can Kim Harrison of Marcin and Angelika's family's legal team now read the summary of pen portrait evidence.

SIR JOHN SAUNDERS: Thank you.

MS HARRISON: Marcin and Angelika are the parents of Aleksandra, Alex, and Patrycja Klis. They were both born in Slawno in Poland and grew up in Darlowo in Poland. Marcin was born on 21 October 1974 and Angelika was born on 2 August 1977. Marcin was 42 at the time of his death on 22 May 2017. Angelika was 39 at the time of her death on 22 May 2017.

Marcin and Angelika were soulmates, they met in Poland in the early 1990s and fell in love. They were married in 1996. Alex was born in 1997, and Patrycja in 2003.

Marcin moved to England in 2004 and then Angelika and their daughters joined him in 2007.

Marcin worked as a courier, then in Tesco, and for the last 4 to 5 years of his life he was a taxi driver.

Angelika initially worked as a cleaner, then she worked as a customer services assistant for Tesco. She had held this job for 10 years.

Marcin liked photography and rock music. Angelika

loved to watch films and to be in the sun. Their daughters remember that:

"Their love for each other was incredibly strong, they were so in love, as if they were teenagers without a care in the world, but most of all they were happy, they were soulmates, and they didn't want to be without each other."

Marcin and Angelika were loved by their daughters, who described them as their best friends and protectors. Marcin and Angelika did everything they could to ensure their daughters had everything they wanted and always put their daughters' needs first. The family would regularly go back to Poland as well as visiting other countries such as Rome in Italy and Egypt.

Every few weeks, Marcin and Angelika planned a family day as spending time with their daughters was what made them happy. Alex and Patrycja describe their parents as:

"Amazing parents, great friends and kind people."

SIR JOHN SAUNDERS: Thank you.

MS CARTWRIGHT: Marcin and Angelika had attended the arena together with their daughters, Alex and Patrycja. Alex and Patrycja went to the concert together and Marcin and Angelika were to pick them up afterwards.

The family entered the arena through the stairwell

that leads from the NCP car park to the arena, shortly after 18.30.

The family went to the City Room through the Trinity Way entrance, arriving at the City Room shortly before 18.45. Marcin and Angelika left the City Room at 18.46 and walked into Victoria Station, before leaving the station through the exit leading to Station Approach.

Alex and Patrycja entered the arena from the City Room at 19.00 hours. Marcin and Angelika seemed to have a nice evening in Manchester and took photographs together.

DETECTIVE INSPECTOR RUSSELL: Marcin and Angelika returned to Victoria Station at 21.45. They entered the City Room at 22.23.40.

Marcin and Angelika stood in the City Room with their arms around each other at 22.28.56. They were standing towards the arena doors. They remained standing in this position until 22.30.59.

Marcin was approximately 5 metres away from the bomber at the time of detonation and Angelika was approximately 4 metres away from the bomber at the time of detonation.

Footage taken by a member of the public within the City Room is available approximately 34 seconds after

detonation. Marcin and Angelika can be seen in some of this footage, which shows that, at 22.31.34, Marcin was lying on his side and appeared to be motionless. Angelika was lying next to Marcin on her side and did not appear to be moving.

CCTV shows Marcin and Angelika lying on the floor at 22.31.58. Marcin and Angelika both appear to have been lying on their right-hand sides with their heads facing down towards the floor.

The sequence of events for Marcin at 22.32.18 records that CCTV continued to capture Marcin at this time and that he had not been seen to move throughout the footage.

Travel Safe officer Philip Clegg entered the City Room just before 22.33. As he walked around the City Room his body-worn video shows that Marcin was lying on his side, motionless, at 22.36.10. Angelika was behind him.

At 22.38.02, CCTV captured Marcin and Angelika again. Both were lying on the floor and neither of them appeared to have moved position since they were last observed nearly 6 minutes before. Sarah Burke, a member of the public, leant over Angelika at this time. He moved away from Angelika at 22.38.04.

Footage then captures Marcin on several occasions,

but he does not seem to move. Mr Clegg's body-worn video shows that at 22.42.59 Angelika was lying on the ground with ETUK arena medic Zak Warburton leaning over her.

At 22.43, Zak Warburton appeared to be assisting Angelika and remained with her until 22.43.22.

MS CARTWRIGHT: Mr Warburton has provided a statement dated 5 July 2021. This statement was prepared following review of his sequence of events. In the statement, Mr Warburton confirms that he would have assisted Angelika but he does not recall any specific detail of his involvement with her.

He confirms that he would be checking for signs of life, such as breathing or a pulse, and that:

"Although the images show me doing so, I have no recollection of approaching Angelika, her injuries and whether she was conscious or not."

DETECTIVE INSPECTOR RUSSELL: At 22.44.30, ETUK first aider Ken O'Connor was stood over Angelika. At 22.45.02, Mr O'Connor placed a T-shirt over Angelika's body.

MS CARTWRIGHT: Mr O'Connor has provided a further statement. This statement had been prepared following a review of his sequence of events. In the statement, he confirms that his sequence of events shows that he covered Angelika. He does not specifically recall

covering Angelika, though he does recall checking on a number of people who he believed to be deceased, and states that he could have covered Angelika out of respect and dignity for her.

DETECTIVE INSPECTOR RUSSELL: At 22.45.10, BTP Police Constable Jessica Bullough stood over Marcin.

MS CARTWRIGHT: PC Bullough has provided a statement dated 21 July 2021 following a review of her sequence of events. BTP PC Bullough explains in the statement that she does not specifically recall any interaction with Marcin.

DETECTIVE INSPECTOR RUSSELL: By 22.50.22, Angelika's head and upper body had been covered by T-shirts.

At 22.50.46, BTP PC Stephen Corke was knelt near several casualties, including Marcin.

MS CARTWRIGHT: PC Corke has provided a statement dated 22 July 2021, following a review of his sequence of events. He confirms in this statement that he checked Marcin's pulse at this time and that he could not detect one. He states that it was clear that Marcin had died at this time.

DETECTIVE INSPECTOR RUSSELL: By 22.53.15, Marcin's body had been covered with a poster. By 22.59.35, his head had been covered with a poster.

Marcin and Angelika are then seen on several

occasions on the body-worn video of the officers that were in the City Room. They both remained covered.

At 23.38.20, Police Sergeant John Whittaker was sitting next to Marcin. At 23.38.25, Sergeant Whittaker lifted the poster that was covering Marcin and appeared to check his pulse.

MS CARTWRIGHT: PS John Whittaker has provided a witness statement dated 29 July 2021 in which he clarifies:

"Having viewed images of [him] checking Marcin from his sequence of events and [confirms] that the images at 23.38.05 and 23.38.41 are examples of me checking for signs of life in the manner I have outlined, and again I would have moved on upon not finding any sign of life. I have no recollection of approaching and checking Marcin."

DETECTIVE INSPECTOR RUSSELL: At 23.39.35, NWAS paramedic Patrick Ennis knelt down between Marcin and Angelika. He turned first towards Angelika and then towards Marcin.

At 23.39.40, Mr Ennis attached a label to Angelika to identify her as deceased.

At 23.40.09, Mr Ennis appeared to be attaching a label to Marcin.

MS CARTWRIGHT: Patrick Ennis has provided a witness statement following review of his sequence of events.

He confirms that he attached a label to Angelika to identify her as deceased at 23.39.40 and that he attached a label to Marcin to identify him as deceased at 23.40.09.

I am next going to read a summary of the conclusions of the medical evidence, which some may find distressing and may wish to leave the room or turn off their feed.

The initial post-mortem for Marcin Klis. The initial post-mortem for Marcin was carried out by Dr Michael Parsons at Oldham Royal Hospital mortuary. His post-mortem report is dated 25 September 2017.

Dr Parsons states that the distribution of Marcin's injuries indicate that he was facing slightly towards the origin of the explosion and that the overwhelming majority of injuries were sustained to the left side of his body.

Dr Parsons confirms that Marcin was declared dead at the scene on 22 May 2017. Dr Parsons provides a medical cause of death for Marcin as:

"1A, chest injuries."

The initial post-mortem for Angelika Klis. This was carried out by Dr Charles Wilson at Oldham Royal Hospital mortuary. Dr Wilson's post-mortem report is dated 11 September 2017.

Dr Wilson identifies that the location of Angelika's

injuries indicated that the blast from the explosion had approached her from her left side. Dr Wilson provides a medical cause of death as 1A, multiple injuries.

Turning then to the evidence of the blast wave experts' panel. The blast wave experts' report is dated 27 September 2019. The report states that Marcin sustained multiple secondary blast injuries with three of particular significance. The written conclusions of the blast wave experts are that Marcin's injuries were unsurvivable with current, as at 2019, advanced medical treatment.

The report also states that Angelika sustained multiple secondary blast injuries, with two of particular significance. The written conclusions of the blast wave experts are that Angelika's injuries were unsurvivable with current, as at 2019, advanced medical treatment.

Turning then to the review by the forensic pathologists, Dr Philip Lumb and Professor Jack Crane.

Dr Lumb and Professor Crane provided a report in relation to Marcin Klis, dated October 2020. Dr Lumb and Professor Crane state that death as a result of multiple injuries would have been very rapid. Dr Lumb and Professor Crane conclude that Marcin's injuries were unsurvivable. This conclusion accords with the

conclusion of the blast wave experts that Marcin's injuries were unsurvivable with current advanced medical treatment.

Turning then to Angelika Klis. Dr Lumb and Professor Crane provided a report in relation to Angelika Klis, dated 8 September 2020. Dr Lumb and Professor Crane confirm that Angelika died at the scene on 22 May 2017. Dr Lumb and Professor Crane state that the epicentre of the explosion was just in front of Angelika and Marcin. Dr Lumb and Professor Crane state that unconsciousness would have been almost immediate and death would have followed rapidly.

Dr Lumb and Professor Crane conclude that the head injury was unsurvivable, even with prompt medical attention at the scene. This conclusion accords with the conclusion of the blast wave experts that Angelika's injuries were unsurvivable with current advanced medical treatment.

Sir, that concludes the evidence summary to be read of Angelika and Marcin Klis. Could we reconvene at 3 pm?

SIR JOHN SAUNDERS: Thank you. Can I just say this. We know that Marcin and Angelika had two daughters, Alex and Patrycja. The night of 22 May 2017 was meant to be a particularly happy occasion while they attended the

concert. Instead, it turned into a complete tragedy for them, which no doubt has affected their lives hitherto and which they will never, ever forget.

But perhaps we were all struck by one passage in the tribute that they gave at an earlier stage, they remember that their parents' love for each other was incredibly strong:

"They were so in love, as if they were teenagers without a care in the world, but most of all they were happy. They were soulmates and they didn't want to be without each other."

MS CARTWRIGHT: Thank you, sir.

(1.51 pm)

(Adjournment)

(3.00 pm)

Evidence summary for COURTNEY BOYLE

MS CARTWRIGHT: Sir, good afternoon. This is the chapter 12 evidence summary for Courtney Boyle.

Present in the hearing room is Courtney's mother, Deborah Hutchinson, Courtney's sister, Nicole Boyle, and Courtney's aunt, Andrea Hope. They are assisted today by their legal representatives and also present in court are the legal representatives for Robert Boyle, Courtney's father.

Please can the photographs of Courtney be displayed?

Please could I ask Mr Duncan Atkinson Queen's Counsel to read the pen portrait summary of Courtney.

MR ATKINSON: Courtney was the daughter of Deborah Hutchinson and Robert Boyle and the sister of Nicole.

Courtney was born on 25 October 1997 in Gateshead. Courtney was 19 years old at the time of her death on 22 May 2017.

The summary of the pen portrait evidence of Deborah Hutchinson.

Deborah, Courtney's mum, was besotted with her from the day she was born. She was a beautiful and happy baby and she grew up to be very close to her cousins, Amy and Ryan, and her little sister Nicole, who was born in 2002.

Courtney worked hard in school and she was determined to go to university to pursue her dreams. She developed a love of music and when she was 16 she got a part-time job to save up to go to Leeds Festival with her friends. It was there she met Callum, her boyfriend. Deborah recalls how lovely it was to see her daughter so happy and positive about her future.

Courtney achieved her dream of going to university in May of 2017. She had just finished her first year at Leeds Beckett University where she studied criminology

with psychology. Courtney was loving life as a student.

She was the happiest Deborah had seen her. In Deborah's words:

"Courtney had so much more confidence and my shy, quiet girl had become a gorgeous woman with a loving, caring nature to match."

Courtney achieved a first in the exams she had taken at the end of her first year at university and she was awarded an honorary degree from the university in July of 2017.

Deborah remembers her beautiful daughter:

"I know that as time goes by, my daughter's beauty will never fade, she will always remain beautiful."

A summary of the pen portrait from Nicole Boyle.

Nicole remembers that Courtney was someone that people would love to be around because of her witty and funny personality. Growing up with her was like growing up with a best friend. Nicole describes Courtney as a safe place for her, explaining how Courtney guided herself, Nicole and their mum through the darker times by, in Nicole's words:

"Shining light on these situations and ensuring we kept a smile on our face. Courtney was an amazingly bright and smart girl, who shone so bright in any place she was and still does today."

Summary of the evidence from Andrea and Alan Hope. Andrea and Alan remember their gorgeous niece for whom they had a special place since the day she was born. Courtney was a massive part of their lives and they remember so many family fun days and telephone calls where the world was put to rights.

They remember Courtney as a beautiful and confident young lady who was loving and caring.

Summary of the pen portrait evidence from Amy and Ryan Hope.

Courtney was close to her cousins since she was born. For Amy, Courtney was her first best friend before Ryan and Nicole came along. When Ryan was born, Courtney became a little tomboy and she and Ryan would play with cars for ages. The cousins always had each other's backs and still do.

Finally, the summary of the pen portrait evidence from Callum Maundrill. He met Courtney at Leeds Festival when she walked into him by chance. They got chatting and the rest was history.

They had the best times of their lives together. For Callum, Courtney made the good times great and the bad times bearable. He spoke of Courtney's beautiful resilience that made her so strong and made her a pillar of stability and support for so many people, friends and

family alike.

She and Callum loved each other to bits. In his words:

"Seeing her blossom into the confident, passionate free spirit that she was still to this day brings me joy."

He described how he was so, so lucky to have bumped into Courtney in that field at Leeds Festival.

Thank you.

SIR JOHN SAUNDERS: Thank you.

MS CARTWRIGHT: Courtney went to the arena with her sister Nicole, mum Deborah, Deborah's partner Philip Tron, and Philip's mum, June Tron.

Nicole was going to the Ariana Grande concert and the others were taking her. Courtney had been picked up from her student accommodation earlier that day and Deborah remembers that they had lunch together and then went holiday shopping.

Courtney was excited about an upcoming trip to Amsterdam with her boyfriend, Callum. The group dropped Nicole off at the City Room shortly after 18.00 hours.

Nicole had a VIP ticket and Courtney had queued with her before Nicole went into the arena. Courtney kept in touch with Nicole during the concert through texts. The group then went for some food before returning to their

car to wait to pick Nicole up. Deborah remembers that she and Courtney were laughing together as they waited in the car.

Courtney went with Philip to collect Nicole. They entered Victoria Station at 22.20 and crossed the footbridge leading to the City Room at 22.22.06.

DETECTIVE INSPECTOR RUSSELL: Courtney entered the City Room at 22.22.11. After entering the City Room at 22.22.11, she stood with Philip Tron near to the merchandise stand. Courtney was approximately 4 metres away from the bomber at the time of the detonation.

At 22.31.09, CCTV shows Courtney was lying on the ground on her right-hand side. She was not moving. She was in the same position at 22.32.07.

CCTV shows Courtney again at 22.38.02. She had not moved position since she was last observed nearly 6 minutes beforehand.

At 22.38.18, a member of the public, Robert Grew, leaned over Courtney.

MS CARTWRIGHT: Mr Grew has provided a witness statement dated 13 July 2021, which was prepared following his review of his sequence of events. In the statement, Mr Grew confirms that he saw Courtney at 22.38.18 and that at this time she was not moving or showing any signs of life.

DETECTIVE INSPECTOR RUSSELL: By 22.51.16, a white poster or paper covering had been placed over Courtney's head. From the video footage available, it has not been possible to identify who covered Courtney.

At 23.38.26, NWAS paramedic Patrick Ennis approached Courtney. At 23.38.55, he knelt next to her and placed a label upon her in order to identify her as deceased.

MS CARTWRIGHT: Patrick Ennis has provided a witness statement following a review of his sequence of events. He confirms that he attached a label to Courtney at 23.38.55 in order to identify her deceased.

I am next going to read a very brief summary of the conclusions of the medical evidence.

The initial post-mortem. Dr Wilson provides a medical cause of death as 1A, multiple injuries.

Turning then to the report of the blast wave experts. The written conclusions of the blast wave experts are that Courtney's injuries were unsurvivable with current, as at 2019, advanced medical treatment.

Finally, turning to the review by the forensic pathologists, Dr Philip Lumb and Professor Jack Crane. Dr Lumb and Professor Crane conclude that Courtney's injuries were unsurvivable.

Sir, that concludes the evidence summary to be read for Courtney.

SIR JOHN SAUNDERS: Thank you. Can I say thank you to the family for attending. Courtney was talented, hard-working and would have had a successful and fulfilling life. As we have heard, after her death, the news came through she had gained a first class honours in her first year exams at university.

Ironically, she wanted to be a criminal psychologist, a dream she would never realise. However good she became as a criminal psychologist, I doubt she would have been able to understand the cruel criminal act that so tragically took her life.

MS CARTWRIGHT: Thank you, sir.

(3.12 pm)

(The inquiry adjourned until 9.30 am on Wednesday, 22 September 2021)

I N D E X