I'm Keith Strauss, the Director of Radiology, Physics and Engineering at Children's Hospital in Boston. My topic for this morning is managing patient dose in fluoroscopic procedures. This is the second of a four part series on fluoroscopy. This image is a shot of the new Carl Zakim Bridge in Boston. This is the one part of the 14 billion dollar "Big Dig" project. that's above ground. With respect to managing fluoroscopy, we have some dilemmas. Fluoroscopically guided interventions may be minor or may be life-saving. The possibility of deterministic injuries may be relatively small or we may have the probability for very severe deterministic injuries occurring. The responsible physician must choose, insome cases, either to continue or to stop the complex intervention. To do that the clinician needs some real time data to balance radiation risk against potential clinical benefits of continuing the exam. We don't want to handcuff the physician by creating regulatory

dose limits for these types of procedures. This has been discussed by some members of the CRCPD, which is the National Conference of Radiation Control Program Directors. We also do not want to inappropriately apply reference levels or reference values. Managing patient dose can be split into these two columns. First, we have the machine design. If we exploit the machine design, we can minimize the exposure rate during fluoroscopy or the exposure per image during the recording of images. We also need to worry about the operation of the machine. We need to work with the operator so that we minimize the fluoroscopy time or we minimize the number of images that are actually recorded during the study. All these things work together, overall, to reduce the total patient exposure associated with the exam. We will talk this morning about some of the requirements of the patient exam. We will discuss state of the art, fluoroscopic

angiographic equipment and how we can exploit the design features that a lot of the manufacturers provide today to minimize patient dose, while we still maintain good image quality. I will say a few words about acceptance testing. I will say a little bit about the importance of training staff and then, I want to wrap this up by talking about some of the real time dose monitoring techniques that have been used and are still available to us. As far as the requirements of the patient exam are concerned, most interventional exams are either vascular or nonvascular in nature. Obviously, if we're studying the vasculature, we're going to be looking at the major chambers of the heart or the arteries or the veins. If it's a nonvascular study, we will be, looking at the digestive tract or doing drainages or punctures of some sort. The patient's size dramatically affects the image quality requirements of the exam. Cardiologists focus their

attention on the heart. Next time you are around a newborn baby, look at the size of their fist. We all know that our heart is, approximately, the size of our fist and that's the size of the anatomy the pediatric cardiologist has to deal with. So, our image quality requirements are extremely high. Patient sensitivity to radiation is a function of age. Certainly, the size of the patient will affect the dose. The size of the patient and whether or not they have to be under full anesthesia or just be sedated is going to affect the number of ancillary people that, also, have to be accounted for in the procedure room. As far as patient's sensitivity to radiation is concerned, if we were to take a group of individuals of different ages and give all of them a whole body dose of one Sievert, which of course, is a relatively high dose, we would expect to see these percentages shown in this slide of radiation-induced cancers over their lifetime. On an average, the percent for induction at this

dose rate is about five percent for both males and females. If you're middle-aged, that drops of to one to two percent You notice that in the first decade of life on this slide the child has a 15% probability of inducing a lifetime cancer, so the child is probably ten times more radiosensitive than a middle-aged adult. For years, we have discussed the need to extrapolate high doses that occurred during the dropping of the two atomic bombs at the end of World War II, down to low dose regions to try and figure out what would occur at low doses. We now have a latent period of 50 years, and we have 30 thousand A-bomb survivors that received doses on the order of five to ten to fifteen rads. A statistically significant excess incidence of cancer at non-extrapolated doses results for doses greater than three rads. This incidence, as shown is this slide, is relatively small, but it is real with respect to the error bars. Patients come in all sizes with a large range in

sizes.The circle represents the neonate, which is barrel-chested and is going to be on the order of 7 or 8 cm, in diameter. The large adult is going to be, as much as, in the 30 cm in girth. The half value layer listed here for 70 kVp is, approximately 3 cm. If the kVp is constant, every added half value layer of tissue , requires a doubling of radiation to properly penetrate the patient. The difference between the neonate and the full-size adult is 9 half valuators in the PA projection, so we need a dynamic range of output on our fluoroscope of 512 to cover this range of patient size. In the lateral projection, it's even more. It's 14 half value layers and we need a dynamic range of 16,000. What does this mean? If you take a standard cath lab or interventional lab that has not been modified with a newborn on the table and we don't modify the machine, the kVp reduces to 45 and the dose is four to five times greater than if our machine is modified and it's operating

correctly in the 70 kVp range. We don't really gain anything in image quality by being at 45 kVp versus 70 kVp and we pay a large penalty in patient dose. The complexity of the exam, whether or not it's a diagnostic or interventional case is going to have a lot of effect on the probability of some rather nasty deterministic injuries occurring. This is a classical example of one from a few years back. The good news is these incidences today are not growing as rapidly as they were four or five years ago, but we are still seeing them. So let's look at image equipment design that's available to us today, that we can exploit to try and maintain good image quality, but yet reduce the overall dose to the patient. One of the more important ones that's been developed in the last ten years is variable rate pulse fluoroscopy. With variable rate pulse fluoroscopy, we're essentially changing the rate at which the pulse beam is turned on and off, per unit time in the

fluoro mode. If we have a cath lab, we're going to want variable rate pulses of 30 to 7.5 pulses per second. If we have a DSA lab, we're probably going to want pulse rates that go down to 4 to 3 pulses per second. If we have a simple fluoroscopic unit, where we're doing GI or GU studies, as little as 1 pulse per second is necessary. If it's a biplane configuration, we need alternating pulsed fluoro, to minimize scatter from the opposite plane degrading image quality. Image quality must always be balanced against radiation dose. What’s the appropriate pulse width to minimize temporal information loss?” We find that in pediatrics anything less than 5 milliseconds reasonably freezes patient motion. In adults, you can use up to about 10 milliseconds. Phil Rauch during his lecture yesterday, showed some examples of what happens with variable rate pulse fluoroscopy with respect to perceived noise as the frame rate is changing. As the frame rate

decreases, the perceived noise in the image increases. This occurs because our eye integrates successive frames of fluoro video. At 30 frames a second, our eye effectively integrates about five images for each perceived image. As we go down to 7.5 frames per second, our eye cannot integrate and the perceived noise increases.So the question is raised, “How much do we increase that exposure per frame?” This equation illustrates that. The increase per frame is proportional to the ratio of 30 frames per second and divide that by the actual pulse frequency and raise that ratio to the one-half power. This relationship was published about ten years ago by Aufrichtig in his PhD thesis. This suggests we need to double the exposure per frame when the pulse rate decreases from 30 to 7.5 frames/sec. Instead of obtaining a reduction in patient exposure of a factor of four that we would obtain if the exposure per frame were fixed, we only have a savings in

dose of a factor of two. Importantly, we have maintained our overall image quality. This is crucial in encouraging operators to use reduced frame rates. We want a tube current of about 10 mA on small children; we need 100 mA on larger patients. This suggests a 0.3 millimeter focal spot on smaller patients for pulsed fluoro and the use a 0.6 millimeter focal spot nominally for adults. We want a desired fixed high voltage of around 70 kVp. We waste dose if the kV is too low for little kids and lose our contrast on larger patients if our kV rises.We’ve talked about needing a dynamic range of output of 500 as a function of patient size. The earliest pulsed fluoro machines did not have the ability to modulate the tube current and the pulse width. Only the kVp was modulated. We had our optimum 70 kVp for only one-size patient. What hierarchy would we like to use to modulate our tube current and our pulse with at the same high voltage? Modulate the tube

current first. Our focal spot will bloom with a little bit of geometric sharpness in our images, but that effect is not as great as the motion sharpness that occurs if pulse widths are increased. Again, some manufacturers use too great of pulse widths with 20 and 25 milliseconds. Continuous fluoro operates at 33 milliseconds per frame. If we operate pulse fluoro at 20 msec per frame, we are throwing away the benefits it brings. Finally, we want to modulate our high voltage last, because we know that’s going to affect the overall contrast in our image.If you have a continuous fluoroscopy machine, instead of a Pulse fluoro machine, again, we want a starting kV of about 70. We would like the machine, to modulate the tube current first and the kVp last. 23. That’s the situation for variable rate pulsed fluoro. What about the variable rate radiographic acquisitions? In the cath lab, we want variable acquisition rates of 30 and 15 pulses

per second. Most manufacturers provide 60. The more confidence and experience that the cardiologist has, the lower the frame rate he/she will be willing to operate at. We do all of our pediatric work very nicely at 30 frames per second. The tube current, again, is a function of the patient size or age. This suggests a 0.3 millimeter focal spot, a 0.6 millimeter focal spot and then the large focal spot on the x-ray tube. We want our high voltage to be at 70 kVp for patients under 12 years of age. As we get to larger patients, the kVp is going to have to increase just to penetrate the patient.In the vascular lab we have a maximum pulse rate of 7.5 frames per second. The tube currents and kVp's will be similar to the cardiac lab. We prefer a modulation hierarchy for radiographic acquisition similar to the hierarchy for the pulsed fluoroscopic mode. About ten years ago, a company introduced spectral beam filtration. Today, the majority of

manufacturers have this capability built into their units. Added filtration to an x-ray beam attenuates the low energy photons and passes the high energy photons. Spectral beam filtration adds a feature. In addition we eliminate the high energy photons which scatter and degrade overall image quality. First we need an x-ray tube with a relatively high continuous loading of 2 - 3 KW in the continuous fluoro mode. We use a relatively thin 0.1 to 0.9 millimeters of copper filter, as a function of patient size. If we do not do anything else, our ABS system is going to compensate by increasing the kVp of the overall image. As a result of that, our effective energy increases. Next we reduce the amount of photons in the beam between 60 and 80 kVp by reducing the kVp to 60. Now the area under my bremstrahlung curve is relatively small indicating a weak x-ray beam intensity. 29. We compensate for the weak intensity by significantly increasing

the tube current. Since these x-ray tubes have up to a 3 KW rating, the effective tube current can exceed 35 to 40 mA. As a result, we get a band of energies in our bremstrahlung beam of 33 – 60 keV. That is not as narrow as we would like, but certainly is an improvement over simply sticking in an additional filtration and not addressing the kVp. For years, systems have had last image hold—the last image "sticks" on the monitor and gives us a fluoroscopic frame that's stored and continuously displayed. It is going to suffer from greater perceived noise for the same reasons that we talked about with variable rate pulsed fluoro, but it does allow the user to see and think about the next steps of the case prior to administering more fluoro.Within the last year, angiographic equipment have been developed fluoro image store and playback that grabs the last 300 frames of fluoro and stores it on the hard drive. You can now play back the fluoroscopic run.

This is a great improvement over storing a single image. Your eye will integrate the replayed run, just as it did when it saw it the first time live. Be aware that a lot of these features are offered by the manufacturers as options so you need to be an informed consumer and ask for them. Spatial beam shaping is important in reducing overall patient integral dose. We do this with equalization filters that in some cases are lead impregnated acrylic. One manufacturer has given the operator the capability to actually change these wedges, by opening the face of the collimator; a nice feature for pediatrics and small patients. 33. Another optional feature with some manufacturers is the ability via an electronic rendition on the screen of the collimator blade location to adjust the collimator blades without the use of radiation. You need no dose to make the adjustment. The argument of the operator who does not want to make the effort to adjust the collimators that says, “I do not want to give the patient extra radiation dose” is gone. We do need to adjust the entrance exposure rate to the image receptor as a result of our spectral beam filtering. The entrance exposure to the image receptor determines the rate at which energy is delivered to that detector. Spectral beam filters increase the effective energy of the x-ray beam. If the same amount of energy is delivered to the image receptor per unit time, less information carriers are in the beam and quantum mottle increases. This is corrected by increasing the entrance exposure rate to the image receptor. This is another example of techniques that reduce patient dose, despite increasing the exposure to the image receptor. All systems today have electronically adjusted apertures in front of the TV camera. This controls the entrance exposure rate to the image receptor and indirectly controls the entrance exposure to the patient. If

you have a flat panel detector system, no adjustable aperture in front of the TV camera exists, but an equivalent adjustment is contained in the machine. This aperture allows the change in the entrance exposure rate to the image receptor as a function of the pulse rate. 37. How else can we exploit this ability to reduce patient exposure? A system with a fixed aperture increased the entrance exposure rate by a factor of four, as we went from a 9 inch to a 4.5 inch field of view. The aperture was fixed and the exposure had to increase by a factor of four to compensate for the loss of minification gain in the image intensifier. The exposure was increased to maintain brightness on the monitor. This leads to a reduction in quantum mottle in the image. 38. Today with an adjustable aperture as a compromise, instead of increasing the entrance exposure rate to the image receptor as 1 over the field of view squared, we change it as 1 over the field of view. A

change from a 9 inch to a 4.5 inch field of view, doubles the patient exposure rate instead of quadrupling it. As we go to a smaller field of view on a conventional image intensified system, we improve the MTF of the image receptor, the sharpness of my image increases, and if the absolute noise stays the same, the perceived noise increases with that sharper image. To compensate and keep the perceived noise constant, the entrance exposure rate is increased as one over the field of view.39. The overall sharpness of a flat plate image receptor is going to be a function of the pixel size in the plate. As you change the field of view of the plate, the number of pixels used to form the image changes, but the physical size of the pixel is unchanged. Sharpness remains relatively unchanged as a function of the field of view. Thus, the entrance exposure to the image receptor should remain unchanged. As we go to a smaller field of view, the image is enlarged on

the monitor and it’s easier to see, but overall image quality is not improved. This is an area where some of the manufacturers are wasting a lot of dose to the patient. 40. Most of these systems allow the operator to select an exposure level and depending on the manufacturer, you may have three levels or two levels to choose from. Typically, the exposure rate between levels changes by a factor of two, relative to one another. Is acceptance testing something that we still need to do? 20 years ago, we found more faulty components and more installation errors than today. Former installations of an interventional lab might have taken five or more weeks. Much of the final setup of the unit is automated by the computers of the system. So, the likelihood of installation errors is greatly reduced. Systems 20 years ago had one way of operating with few choices the end user needed to make to affect the overall image quality or the overall dose to the

patient. Other speakers are going to talk about the variety of image processing on all these machines and choices that need to be made. And as a result of that, I would say that acceptance testing to insure correct functionality with respect to expectations is just as important today as it used to be. Once the above choices are made, you need to measure the entrance exposure rate to the image receptor in all fluoroscopic modes and all recording modes to make sure you're delivering the correct exposures to the image receptor. You also not need to measure the entrance exposure to the patient at the maximum output of the machine, and over all modes of operation and at all patient sizes that are actually going to be studied by the equipment. And please do not assume that the installer has addressed these issues. Today the manufacturers boast that their installations require two instead of six weeks time. This is possible because they

do too little functional testing of their installed equipment. 43. So, what are the appropriate performance levels? We have talked about all of these entrance exposures to the image receptor that appear here as a summary. All of these are relative values. I have not said anything about absolute exposure levels to the detector. What determines the appropriate performance level for the entrance plane of the image receptor--adequate image quality? I did not say excellent image quality. We need adequate image quality to make the diagnosis. This is going to be a function of the diameter of the vessels to be imaged, the concentration of contrast material chosen, and the equipment design. The above three things are going to affect what an appropriate minimum exposure rate might be to the image receptor. The Rose model predicts what we need to do with exposure. It is proportional to 1 over p squared, c squared, d squared, where p is the precision or

the level of quantum model in the image; c is the concentration of contrast; d is the diameter of the vessel.The Rose model predicts a minimum exposure to detect the contrast filled vessels. We are doing a disservice to our operators and patients if we use less exposure than that. But the Rose model incorrectly predicts that any increase in exposure is going to improve our overall image quality because the perceived noise is reduced. This is incorrect because the overall perceived noise that we see in the image is a function of the quantum model and the electronic noise in the system which add in quadrature, as shown here. 47. When increasing entrance exposure to the image receptor, quantum mottle must exceed electronic noise. If quantum mottle is equal to our electronic noise, further increases in exposure to the image receptor are wasted. Overall image quality is actually degraded on large patients. Patient girths that require more than

the maximum 10 R per minute will have suboptimal brightness on the TV monitor due to improper penetration. As the entrance exposure rate to the image receptor increases, the ability to penetrate large patients is degraded. 48. If you have a conventional image intensifier with a 22 cm field of view at 80 kVp with standard filtration, standard kVp, standard power curves, and at 30 pulses per second, 1.5 to 2.5 µR per frame at the image receptor is appropriate. High dose fluoroscopy typically uses double the standard fluoroscopy rate. 50 to 100 µR per frame is recommended for digital angiography (DA).

Digital subtraction angiography (DSA) requires approximately ten times more exposure per frame. In DSA weak signals are amplified. This also amplifies the absolute noise in the image increasing the perceived noise. The perceived noise is reduced by increasing the entrance exposure to the image receptor. In cardiac digital, 8 to 10 µR

per frame is somewhat less exposure per frame than the conventional cine film. This is the case for a standard image intensifier. 49. What about the flat plate detector? For a 20 cm detector at 80 kV, at 30 pulses per second, with standard filtration and standard power curves the recommended entrance exposure is the highest value recommended in the previous table, 2.5 µR per frame. The sharpness in the image and the overall image quality on all fields of view of the flat panel are approximately equivalent to the most magnified mode on a standard intensifier—4.5 inch field of view. The digital angiography and the cardiac digital values are similar to the recommendations for the image intensifier. 50. As the field of view changes on the flat panel unit, the exposure rate to our flat panel detector should remain unchanged for the reasons that we already talked about. What are appropriate performance levels for the entrance

exposure rate to the patient? The first question we need to answer is "Where do you measure it?" Where is the patient? Do you measure it at the patient's skin? Do you measure it at a reference point? We have three different typical geometries of patient and machine. A mobile C-arm has a fixed source to image receptor distance (SID). A conventional fluoroscope, has a table top or skin entrance plane of the patient that is fixed relative to the focal spot. An interventional room that's capable of compound angles has a fixed axis distance, or isocenter, the distance from the point of rotation to the focal spot. Obviously, The conventional fluoroscopic table allows movement of the image intensifier relative to the table top, but the majority of these systems, do not allow you to change the distance between the focal spot and the entrance point of the patient. 53. What are the common dose reference points? The IEC developed a standard defining the point of

measurement 15 cm back towards the focal spot, away from the isocenter. The FDA recommended a measurement point 30 cm away from the image intensifier entrance plane. The two standards define two different reference points. 54. Besides where we make the measurement other important parameters that affect the entrance exposure rate to the patient are the tube current, the kVp, added filtration, and the presence of a grid in the beam all these things along with the inverse square law are going to affect what our typical entrance exposure rate is going to be relative to a given exposure rate to the image receptor.If you have a fixed SID or a mobile C-arm, as your patient increases in size, as shown here, the SSD is going to get shorter. More attenuation in the patient occurs. Both of those factors together are going to dramatically increase the entrance exposure rate to the patient at their size increases. With fixed SSD, a

conventional fluoroscopy room, your attenuation increases as the patient gets thicker. The SID becomes longer. The source to skin distance is going to be fixed. The increase attenuation and longer SID results again in more skin dose to the patient.In the case of the special procedure room, again, our thicker patient is going to create a greater attenuation factor. The SID becomes longer because the image receptor is going to be moved away from the focal spot. A shorter SSD occurs because we want to keep the center of the patient at the isocenter of the machine. I do not have time to go into these measurement pitfalls this morning. Lou Wagner and others published a task group a number of years ago about the performance parameters of concern for our dosimeters. Energy response is more complicated today with spectral beam filtered machines. Collection efficiency of the ionization chamber can be a problem with some of the higher kW

ratings of current x-ray tubes. Leakage is important. Your phantom and how that affects scatter to your chamber determines the appropriate corrections that you need to make as you're measuring your entrance exposure rates. What about the issue of training? We have talked about reducing the exposure rates of the machine, but we also need to make sure the operators know what they are doing. This minimizes the number of recorded images and the amount of fluoro time. Operators that get poor training make the same kind of mistake that B.C. is making here in this slide. Neither the image quality that the machine is capable of producing nor the radiation dose to the patient is optimized. What kinds of training are needed? The operator needs some core knowledge about basic imaging principles, quality control responsibilities, equipment care and maintenance, and radiation protection principles. Within the radiation protection principles,

operators need to know about the principles of x-ray production, patient operator geometries, and appropriate use of shielding devices. A credentialing program is needed to offset the lack of knowledge of the operators that are not radiologists. Credentialing can take a lot of forms. Some institutions are moving to web-based solutions with didactic material, in power point presentations along with exams for the user to take. Most institutions, instead completing all aspects of training correctly, depend solely upon "buttonology" training. "Buttonology is the unique operational features of a specific imaging piece of equipment provided by the vendor's application specialists during the first week of use of the machine. This is a very necessary component of overall training. We can use other clinical sites, the vendors' headquarters, and phantoms to assist with this training. While this is a very important step, the operator needs a good foundation before we

apply this level of training, a foundation best created by a good credentialing programs and regular in-services that the operators can take advantage of. 64.Operators need real time dose information so that they can make informed risk benefit decisions for their patients? We also would like to have some documentation of individual clinical exposures. This allows the management of the radiation risk to the patient and personnel and changes in equipment performance. For additional reading on this topic, I refer you to a paper that was written by Balter, Shope and others that was published as part of the 2002 AAPM summer school proceedings titled "Techniques to Estimate Radiation Dose to Skin During Fluoroscopy Guided Procedures." I am goint to discuss a few highlights of the information in that paper.66. What is the best indicator of patient risk? Historical measurements have been limited by available instrumentation.

Some people record fluoroscopy time. Individuals have used TLD's to measure skin dose measurements. There are devices out there that do real time cumulative skin dose measurements. But ideally, with respect to deterministic injuries, we want to know what the peak skin dose is? What are the limitations of fluoroscopy time? The fluoro dose rate is going vary dramatically, as a function of patient size. You put a 150 lb patient on a well-designed cath lab and two to three roentgen per minute will be the entrance exposure during fluoro. A newborn baby will result in half a roentgen, or a quarter of a roentgen per minute. Patient size will affect exposure rate dramatically, as will kVp, mA, beam orientation, and the other parameters listed here. Fluoroscopy time also does not account for the doses associated with recorded images. Fluoroscopy time is a expedient thing to write down in the patient record, but it really does not

mean much with respect to overall dose.68. The cumulative dose, the total dose delivered during the exam, can be measured real time. Typically the dose at a reference point is estimated based on direct measurements at other locations. The classic example of that is the dose area product meter or the DAP meter. The integral dose across the entire x-ray beam is directly measured and and is used to estimate an upper limit of total energy absorbed by the patient. It geometry looks something like this diagram. The focal spot is at the base of the diagram. The isocenter (A) is where the center of patient anatomy should positioned. “D” is the actual DAP meter, with a KERMA chamber in the central portion at “C”. If wedge filters are involved, “G,” is the region of reduced dose to the patient and the DAP meter reading will account for that. 71. One advantage of the DAP meter is it’s relatively simple to install and set up. The DAP

meter reading is independent of the distance between the ionization chamber and the focal spot. It can be used as a teaching tool for the scatter production during the case. it is an indication of the overall integral dose to the patient. 72. One of its disadvantages is the lack of correction for tabletop attenuation. Since the source to skin distance is not known, we can not accurately estimate the average field of view at the patient during the exam. Without this knowledge, we can not estimate the entrance exposure unless the central region within the ionization chamber is insulated from the peripheral areas of the ionization chamber comprising the DAP meter. Unfortunately, many manufacturers still do not provide this so skin dose estimations may contain some inaccuracies. 73.

There’s another device on the market that derives patient exposure by determining the exposure rate and the cumulative exposure at a reference point from real time

data within the system. If I know the kilovoltage, the tube current, the time, the source to skin distance, appropriate calibration algorithms for the unique output of x-ray tube and how much attenuation occurs in the patient support system, I can calculate entrance exposure. This device actually does that and displays the cumulated dose to that point in the exam when the foot pedal is not depressed. When the foot pedal is depressed, you get the entrance exposure rate at that point in time. This device requires considerable effort to install it and keep it calibrated. Good noise-free interfaces to the x-ray machine are needed to get your signals. It does provide a data-base to store the dose data, but the data-base requires some maintenance. It does not give you any information about the spatial distribution of the entrance beam. You can not calculate the peak dose from the cumulative dose. The peak skin dose will not equal the cumulative dose unless the skin port through the entire exam is unchanged. The entrance port moves during the exam depending upon the beam orientation in the field of view that the operator selects. The dose for a given port is dependent upon the “on time” and the intensity of the beam through that portion of the exam. The operator needs information about overlapping of the individual skin ports.A system was available ten years ago called Care Graph that provided information about the individual skin ports and any degree of overlap. The skin was modeled to one standard adult body size. Different sizes of patients were not addressed by the device. Unfortunately, it was relatively expensive and very few people bought it. During this case two individual skin ports were utilized. We see no overlap of the skin ports. The inset in the slide is the same patient using some direct exposure film, to indicate where those actual ports were on the backside of the

patient. Other direct methods of measuring skin dose have used Thermo luminescent Dosimitry, or TLD’s. They are small in size and not seen in the image. Unfortunately, real time feedback is not provided to the operator We also do not know if we were fortunate enough to locate an individual TLD at the location of the actual peak skin dose. 81. One set of researchers was clever enough to take an array of TLD’s and put them in this plastic wrap, measure the TLD’s, and use an Excel spreadsheet to plot some isodose curves on the back of the patient. Again, real time information is not provided. X-ray film is available to us today for dosimetry. This provides a dose distribution that is illustrated. It can be used with any x-ray unit and can provide quantitative dose information. Among its disadvantage are a limited range, many factors that can affect its sensitivity and its limited range of calibration. One also must be careful about the

positioning it with respect to the patient. No real time feedback is provided. Finally, a radiochromatic film is available; a chemical reaction changes the color of the film in response to radiation dose. It does not require development. Calibration data contained in figures as illustrated are available for this film. This image compares the results of film versus this radiochromatic material. If one knows the total skin exposure to the patient along with some of these film exposures illustrating distribution of the skin ports for some of your standard exams, one can begin to predict the peak skin dose. In conclusion, we need to verify that imaging parameters are optimized on new systems. If we do this as physicists, image quality will be improved. The entrance exposure rate to the image receptor may not be lowered, but it will be optimized. If the entrance exposure rate to the image receptor is optimized, the entrance

exposure to the patient should be optimized. We need to monitor our clinical exposures to allow our operators to make some informed, proactive risk-benefit decisions. The day is coming, when all of this will need to be documented To achieve all this, the physicist needs to understand the design of the equipment and it’s limitations. We also need to understand the actual clinical demands of the individual clinicians who will operate the equipment.