Aspects of Implementing Electronic Brachytherapy

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Good afternoon actually. Good to see a wonderful turnout here today. Moving more towards the theoretical, towards the practical clinical aspects that we as medical physicists would need to implement this new technology once it becomes FDA approved; of course, we need the calibration in place, so I'm gonna focus the talk on more things that would interest, I think, more of the clinical medical physicists once this would be in their clinic. As with all new technology, there often is not an opportunity for the AAPM or other groups to weigh in on clinical guidance. I think that as this technology, as this system, becomes more . . . is rolled out, there needs to be some addressing of the guidance that we as physicists should follow, as well as so that when we do things properly then things are done consistently around the land. We wouldn't want there to be exceptionally high QA and proper procedures done only, let's say, in Boston; whereas, if you go to another state or another city, that there would be lax attitudes on such matters. So, one thing that we're working with the company on is trying to set some voluntary standards, in the absence of AAPM and other groups not having things applicable at this time. In addition to that though I'm going to focus mainly on the treatment planning aspects, the . . . as you know, I'm involved with various working groups and subcommittees in the AAPM towards investigating this brachytherapy dosimetry formalism and trying to make things consistent and applicable for physicists. Looking here then at the measurements and calculations which exist for characterizing the dose rate distribution around the source, and then also the standards as Larry mentioned regarding calibrations. I think many of you are familiar with the brachytherapy geometry; the coordinate system that's used. We prefer to use a polar coordinate system with r being the distance and θ being the angle from the long axis of the source. I'll show . . . as you've seen from the slides earlier, that the x-rays are omitted from the tip of the source. There is actually no length, no active length, that would be needed for characterizing this source. It acts like a true-point source with an active length, if you will, less than 1 mm. It's a high dose rate source but with some novel characteristics in comparison to what we're commonly familiar with. Here is the two-dimensional formalism where there should be a dot here; I guess it didn't come through. The dose rate to water at a point typically characterized like this where you'll have the length for the geometry function, 2-D approach, and then the radial dose function, also using the same geometry function, line source approximation there. But that really does not apply as we've mentioned in that the length is near zero; it's actually less than one millimeter as I had said. So in fact, one can have a novel dosimetry formalism applied for this source that's both a function of distance and angle; and you would need that because there is some significant anisotropy to this source as there are all other HDR sources. You need to characterize that aspect here, but yet the geometry function we can just use a simple $1/r^2$ as you see here. Here are some spectrum; people are fairly familiar with Cobalt-60 and I-125 spectra. This is a broad spectrum, as you'd expect similar to an x-ray tube from your simulator, except we're down to 50 kV here. This showing at these distances what the average energies would be at the bottom there, fitting in very similar to the iodine-125 experience, but again, this is a high dose rate source. That was showing some calculations of the spectrum here. Here's showing the measurement methodology using the PTW; a very small ionization chamber, yet applicable through the lower energy x-rays that would be measured. That's on a precision stage and then, in addition to those measurements, Monte Carlo calculations using the latest version of MCNP, as well as the corrected cross-section libraries. I've been burnt in the past using outdated cross-section libraries. These are, you could almost say, incontrovertible. These were then used for calculating transport *de novo* from an electron source impinging on the target within the x-ray source. These calculations were not performed saying, “Let there be photons” rather “Let there be a monoenergetic electron source” and watch it from there and follow the histories. The measurements having a one-standard deviation of less than 5% for the various three operating voltages as presented and they're in very good agreement with the Monte Carlo results. Here data is shown from one to seven centimeters. I admit it's probably hard to see back there the lines; but here would be the 50, the 45, and the 40 kV settings and the lines, the dash lines are the Monte Carlo results; where the measured results are the icons, be it the triangles, square, diamonds. I know this is a log plot and perhaps maybe showing this as a ratio would be more telling but because the dose rate falls off so quickly, or covers a large range, I think it's useful to present all the data like this. This actually - well I stand corrected. This is not the dose rate as much as this is the radial dose function, so it already has divided out to the $1/r^2$. Then here, as I mentioned, the only HD . . . at this moment, the most common high dose rate remote afterloading source out there is for iridium-192, so HDR Iridiumi192 is really what this source I think would be competing with; yet, as we've mentioned, we're seeing average energies which are very similar to I-125 so it's kind of an unexplored niche of . . . this is in effect an HDR iodine-125 source and yet it's not radioactive. That's how I kind of like to think about the dosimetric properties. Here's showing the dose rate now, not the radial dose function, as was showed previously. Here's showing the dose rate for the 50 kV setting in comparison to iridium. So we see for HDR iridium that, in fact, at near distances, this Xoft source has an even higher dose rate, but I mean it's certainly in the ballpark of a 10 Ci iridium source as far as the dose rate. But, as we've mentioned, the dose fall off . . . again look comparing the blue 50 kV setting that is quite similar to the dose fall off of I-125; just many orders of magnitude higher. We mentioned about anisotropy; all HDR sources have an anisotropy. Here the source is normal. Here is for that function's normalized to be unity at 90°. We see at a couple distances here, 3 and 5 cm, that it's typically less than 20% in the forward direction and then obviously due to the forward direction of the electrons and pitching the target, as well as the construction of this source, they'll be significant attenuation towards the direction in which it's being retracted. You can read here that, what I think, are very good levels of agreement between the measured and calculated results. As pointed out here, $F(r,\theta)$, very slowly for greater than 2 cm. Basically all the anisotropy values, all the curves, would fall on top of each other pretty much within, let's say, 5% for distances of 3, 4, 5, 6, up to maybe 7 cm. So I won't belabor this slide as it looks like Larry covered this in great detail about the approach being taken for calibrations. Just pointing out here the air kerma strength that is much higher than a, well about a factor of two maybe higher in a 10 Ci iridium source; just that it's attenuated more so and thus it was producing dose rates at 1 cm from this balloon producing dose rates pretty similar to the iridium. Here are some radiochromic film results from Sou-Tung. I don't know if she is in the audience? Her work is acknowledged. There we go, right there! Showing differences . . . showing actually I think a nice comparison between measured dose, as observed by film, compared to what was intended to be delivered through the planning system and there's very good agreement. And a take-away message that I could make is that the TG-43 formalism with, let's say, the improvement that I mentioned of using $1/r^2$ for an HDR source, instead of where the length is effectively zero or less than 1 mm; that this formalism is entirely applicable and that parameters can't . . . values of parameters such as the radial dose function, that those things can be determined and used properly in a conventional treatment planning system environment. Here . . . I do apologize, this one is not visible, but here then showing the values of the anisotropy $F(r, \theta)$ so I had mentioned that that . . . it's a tractable problem and it's been solved as far as characterizing the measured and calculated dose rate distributions and then backing up and determining what the values of those parameters would be; measured obviously in a variety of ways, not just one detector at one place but with film and with multiple chambers etcetera. Then I want to put my two cents in here as far as what I think might be the advantages of this system as far as taking a historical perspective on where we've come with teletherapy with, let's say, radionuclide-based cobalt-60. I mean, yes, very dependable, we like that its energy and output is very – as physicists we can use the half-life calculation very readily, but there are advantages to modern electronic approaches; and without having the clinical experience yet at this time where – this is kind of like your consumer reports graph where you're showing how well the microwave that your gal wants to buy if it's . . . if you should get that brand or another. I'm . . . this is not quantitative by just as far as some of the advantages; I think there are potential advantages here. Of course, all these things need to be realized through experiences as we make progress in this effort. In summary, the dose distributions have been characterized, the parameters have been obtained, that due to – and this is something that I want to point out with my observations; that the tube's stability . . . sure you're gonna want to measure output for each tube. You're going to want to measure it maybe for each treatment, preceding each treatment, but the way that the tube has . . . the current tube design, the way that it behaves, is that the output will not slowly go up over time or slowly go down over time. It pretty much will tend to remain stable and then just pop. Kind of like a light bulb. We don't watch light bulbs varying, I know it's an analogy, but we don't see light bulbs getting much brighter or much dimmer as a function of time; they just typically go. So that's the analogy that I've observed for data on this tube regarding stability; both in general for the output but then in regards to the dosimetry parameters. It is in my opinion a very unrealistic expectation for physicists to go and measure the radial dose . . . measure the dose distributions and check on a regular basis what these parameters would be. I just wanted to spell that out here. Then this last bullet is basically summarizing the table that I presented before. That's all I have to say. Thank you, and we'll open this panel for discussion.