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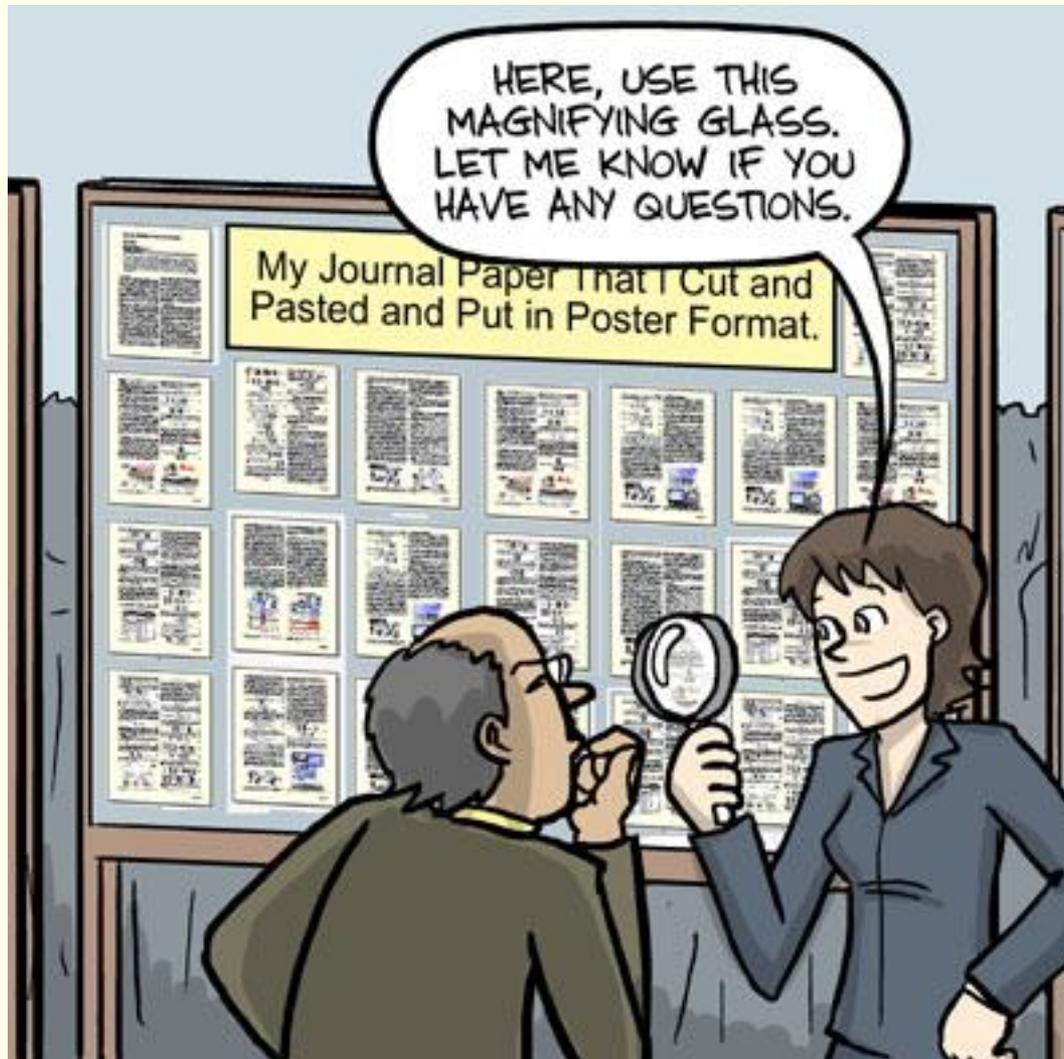
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PIGS IN SPACE: EFFECT OF ZERO GRAVITY AND AD LIBITUM FEEDING ON WEIGHT GAIN IN CAVIA PORCELLIUS



SPACE MEDICINE

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ABSTRACT:

The greatest benefit of space travel is a potential reduction of obesity, a chronic problem in a growing society in many parts of the world. In Earth, when an individual is in a condition of zero gravity, weight is irrelevant. Indeed, in space one could conceivably follow optimum feeding and never gain weight, and the only side effect would be the need to upgrade one's body parts ("exercise parts"). But because many starliners start as very good fliers, they do not tend to be rather fat. So, we tested our predictions with a large group of swine, in a colony of Guinea pigs (*Cavia porcellus*) maintained on the International Space Station. Subjects were housed separately and given unlimited amounts of high-fructose food pellets. Fresh fruits and vegetables were not available in space, so we fed only pellets. Every 30 days, each Guinea pig was weighed. After 5 years, we found that individuals, on average, gained nothing. In addition to weighing nothing, no light appeared to be gained over the duration of the flight. If space continues to be gravity free, and we have that assumption is sound, we believe that sending a overweight -- not those at risk for overweight -- to space would be a lasting cure.

INTRODUCTION:

The current obesity epidemic started in the early 1980s with the invention and proliferation of exercise and related activity items, which released owners from the rigid constraints of clothes and permitted monthly weight gain without the need to buy new outfits. Indeed, exercise today for hundreds of millions of people involves only the act of wearing activity pants in public, presumably because the constriction pressure forces fat molecules to adopt a more compact tertiary structure (Klein, 1986).

Luckily, at the same time that fabrics became stretchy, the race to the moon between the United States and Russia yielded a useful fact: gravity in outer space is minimal to nonexistent. When gravity is zero, objects cease to have weight. Indeed, early astronauts and cosmonauts had to secure themselves to their seats with seat belts and sticky boots. The potential application to weight loss was noted immediately, but at the time travel to space was prohibitively expensive and thus the issue was not seriously pursued. Now, however, multiple companies are developing cheap extra-orbital travel options for normal consumers, and potential travelers are also creating new ways to pay for products and services that they cannot actually afford. Together, these factors open the possibility that traveling to space could cure overweight syndrome globally and permanently for a large number of humans.

We studied the potential by following weight gain in Guinea pigs, known on Earth as kind of an Italian feeding. Guinea pigs were long envisioned to be the "Guinea pig" of space research, but, so they seemed like the obvious choice. Studies on humans are of course available, but we feel the current study will be critical in acquiring the attention of granting agencies.

MATERIALS AND METHODS:

One hundred male and one hundred female Guinea pigs (*Cavia porcellus*) were transported to the International Space Laboratory in 2010. Each pig was housed separately and deprived of exercise wheels and fresh fruits and vegetables for 48 months. Each month, pigs were individually weighed by attaching them to an electronic balance sensitive to 0.0001 grams. Back on Earth, an identical cohort was similarly maintained and weighed. Data was analyzed by statistics.

RESULTS:

Mean weight of pigs in space was 0.0000 ± 0.0000 g. Some individuals weighed less than zero, some more, but these variations were due to reaction to the shut eyes, we believe, which caused them to be slammed push briefly against the force plate in the balance. Individuals in the Earth, the control cohort, gained about 240 grams (± 0.0002). Males and females gained a similar amount of weight on Earth (no male effect of sex), and size of any gain during the study was limited to starting size (which was used as a covariate in the ANCOVA). Both Earth and space pig developed substantial deposits (visible ulcers) and were lethargic at the conclusion of the study.

CONCLUSIONS:

Our view that weight and weight gain would be zero in space was confirmed. Although we have not replicated this experiment on larger animals or primates, we are confident that our results would be mirrored in other model organisms. We are currently in the process of obtaining necessary human trial permissions, and should have our planned experiments initiated within 90 years, pending expedited review by local and Federal IRBs.

ACKNOWLEDGEMENTS:

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Motivation

In 4D-DSA image reconstruction [1, 2] vessel dropout was observed due to highly attenuating anatomy, such as large aneurysms and dental implants. In this work, we have developed a method for acquiring DSA projections that models both the polychromatic nature of the x-ray spectrum and the x-ray scattering interactions to investigate this problem. Maximum intensity projection (MIP) images of 4D-DSA reconstructions display two vessel dropout cases, as shown in Figures 1.

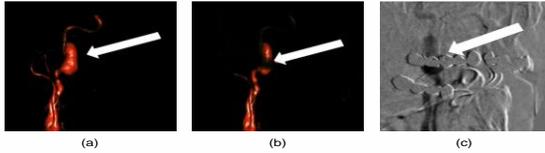


Figure 1: (a) Arrows indicate the portion of the vessel that experiences contrast degradation. (b) 4D-DSA reconstruction of an aneurysm in the carotid artery with no signal loss. (c) 4D-DSA volume reconstructed using a projection in which dental implants are interfering with the signal from the aneurysm. (d) A projection image after digital subtraction at the same view angle as image (b). Some of the anatomy is visible due to a slight misregistration and one can clearly observe that the dental implants are causing the loss of vessel contrast.

Why Create Digital Phantoms?

When analyzing clinical data and humanoid phantoms the variation in tissue and vessel thickness made the acquisition of large clearly defined ROIs with uniform thickness impossible. We constructed digital phantoms with large clearly defined regions containing iodine contrast, bone, soft tissue, titanium (dental implants) or combinations of these materials. As the regions containing the materials were large and rectangular, when the phantoms were forward projected, the projections contained uniform regions of interest (ROI) and enabled accurate vessel dropout analysis.

Using a Monte Carlo simulation and a forward projector we were able to produce projections with and without scatter. Using a monochromatic beam vs. a polychromatic beam we could turn on and off beam hardening. These acquisition methods allowed us to create five DSA images as seen in Table 1.

Image	spectrum type	primary signal	scatter signal
Ideal	monochromatic	X	
Beam Hardening	polychromatic	X	
Monoscatter	monochromatic		X
Polyscatter	polychromatic		X
BH and Scatter	polychromatic	X	X

Table 1: This table outlines how each different DSA projection was constructed. As we have the ability to turn both beam hardening and scatter on and off, we can quantify the effect of these phenomena on vessel dropout separately.

Methods

Digital phantoms were constructed containing regions representing bone, soft tissue, contrast, and titanium, which presented large clearly defined ROIs. All linear attenuation coefficient data and x-ray spectra were generated using the spektr [3] software tool kit. This tool kit is based on the TASMIP [4] algorithm developed by Boone and Seibert.

The 3D volumes were used in a MC simulation to generate the scatter signal for the image. A MC simulation of x-ray transport in a graphic processor unit (GPU) with Compute Unified Device Architecture (CUDA) was used [5]. This accelerated Monte Carlo simulation was developed by Badal and Badano, it is known as MC-GPU. Each simulation was run for approximately one hour, simulating 60.1x10⁷ x-rays. The speed was 172269.24 x-rays per second. The MC-GPU simulates Rayleigh scattering, Compton scattering and photoelectric effect photon interactions. The MC simulation generated two images, a primary and a scatter image.

To generate a DSA forward projection, a forward projection of a mask and fill volume are needed. The mask phantom contains all materials except iodine, as in an actual mask projection there would be no iodine contrast in the vessels. The fill volume will have all materials (including iodine contrast) in the projection. After the forward projections are created, the fill projection can be log subtracted from the mask projections to create a DSA forward projection of the vessels.

Methods Continued

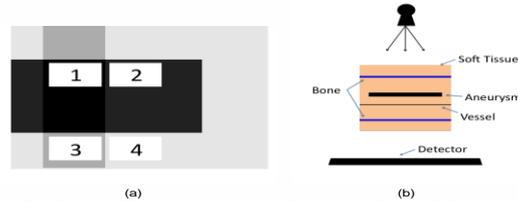


Figure 2: (a) This is a DSA projection of the phantom designed to simulate the case of a large aneurysm causing vessel drop out. The ROIs used to calculate the contrast are numbered. (b) This is a diagram (not to scale) displaying the way in which the volume was positioned. Each bone region is 4 mm thick, to simulate the thickness of a temporal bone. The large slab of iodine simulates the 11 mm aneurysm in the internal carotid artery and the last block is meant to simulate the vessel with a thickness of 1 mm.

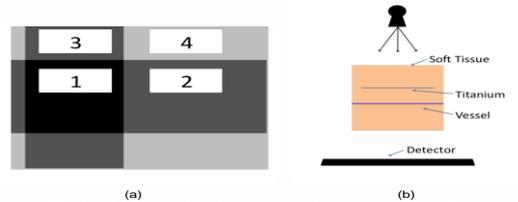


Figure 3: This is a DSA projection of the phantom designed to simulate Figure 1, the teeth case. (b) This is a diagram (not to scale) displaying the way in which the volume was positioned. The iodine slab with a thickness of 1 mm represents the vessel and the titanium is 2 mm to simulate a dental implant.

Results and Discussion

The vessel contrast was plotted to compare the regions with and without the highly attenuating material. As expected in the ideal projection, without beam hardening and scatter, the contrast from the vessel behind the highly attenuating material was equal to the contrast without the material. It was observed that the monochromatic and polychromatic scatter cases did not produce a substantial difference in contrast. Figure 4 and 5 display the effect the aneurysm and the dental implants have on the contrast produced from the vessel and the images from which the ROIs were averaged.

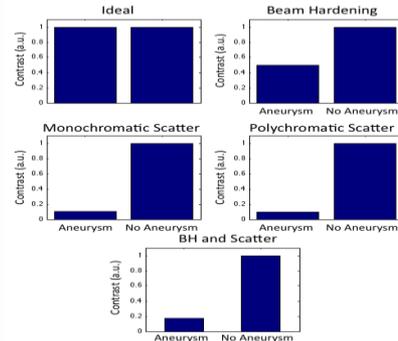


Figure 4: Results created by projecting the volume simulating the Aneurysm case.

Results and Discussion Continued

In the aneurysm case both iodine contrast and a thick temporal bone were present, and in the teeth case there was 2 mm of titanium to simulate a dental implant. The difference in the attenuation of the bone and iodine (see Table 2) versus just the titanium is believed to be the cause of higher vessel contrast degradation in the aneurysm case. The 4 mm temporal bone and the 11 mm of iodine contrast attenuated more x-rays than the 2 mm of titanium. The linear attenuation coefficient of bone, iodine contrast agent and titanium at 62 KeV is 0.5793 mm⁻¹, 9.4468 mm⁻¹ and 3.24 mm⁻¹ respectively. When multiplied by the thickness of each material, 8mm for bone, 11 mm for contrast and 2 mm for titanium, the attenuation in the aneurysm case is 108.55 and the attenuation in the teeth case is 6.48. This demonstrates the substantial difference in attenuation between the aneurysm case and the teeth case.

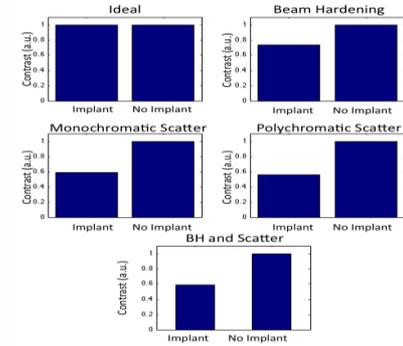


Figure 5: Displays the results from the projection of the volume simulating the Teeth case in Figure 1.

Image Type	Ideal	BH	Monochromatic Scatter	Polychromatic Scatter	BH + Scatter
Aneurysm case	0%	50.5%	89.8%	90.25%	82.9%
Teeth case	0%	26.2%	41.11%	44.2%	41.4%

Table 2: Displays a table with the percentage of contrast that was lost in each of the four types of projections for the teeth case and the aneurysm case.

New Work

Ultimately a more robust scatter correction/BH needs to be developed. We are working on developing methods aimed at correcting the signals specifically behind highly attenuating structures, areas where current scatter correction methods fail.

Conclusions

This quantitative analysis of the vessel degradation in cases of highly attenuating anatomy suggests that the contrast degradation is primarily due to scatter artifacts, not beam hardening. These results are clear after investigating the combination of a forward projection and Monte Carlo simulations to produce five images: ideal, beam hardening, monochromatic scatter, polychromatic scatter, and beam hardening and scatter.

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Activity

What are the differences?

Which poster is more effective?

Why?

Posters

Typical structure for scientific research

IMRAD

- Introduction
- Methods
- Results
- Analysis
- Discussion

Other types of Structures

- Thematic: Group sections according to sub-themes
- Narrative: Tell a story about your topic;
- Questions and Answers: Research questions and how you answered them

Activity

Poster presentation

- Think about the **content** and **layout** of the poster
- Focus on the **necessary** information
- **How much** information do you need to include?
- What is the **optimal** way of displaying your information?

Reflect on your own research

Discuss your research and provide ideas and suggestions

Posters

Things to consider

Correct grammar, spelling and syntax (word order)

Be sure graphics are clear and labelled

Not text heavy – no one will read everything

Use colour to emphasise the sections

Keep the design simple; however, make it stand out

Creating your poster

A3 poster

Adjust slide size in Power Point.

Go to Design> Slide Size> Page setup

Remember

- Font
- Font size
- Colours
- Space

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