Catheter DT20190930

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This document describes models for describing the arterial input function (AIF) in vivo.

1. INTRODUCTION

The arterial input function (AIF) provides the boundary conditions for tracer kinetic problems. The boundaries are Gaussian surfaces across which tracers migrate by fluid mechanics and satisfy continuity equations. In general, the AIF cannot be directly measured for arbitrary volumes such as anatomical structures in vivo. The most common direct measurement obtains from cannulation and automated sampling of the radial artery. The cannulating catheters introduce additional delays and dispersions which require correction. There are also delays and dispersion that are discrepant between the AIF measured at the radial artery and AIFs which describe the internal carotid artery, basilar artery or distal arterioles. Consequently, a model of the AIF is always necessary. The classes *Catheter* in this package provide such models.

All source codes, testing codes, documentation and ancillary data are available at `https://github.com/jjleewustledu/mlswisstrace`. All Matlab codes are packaged as `mlswisstrace` unless indicated otherwise.

2. GUIDELINES FOR GOOD WRITING [1]

The essence of expository writing is the communication of understanding through a clear and concise presentation of predominately factual material. Most people cannot compose successful expository prose unless they put the need to communicate foremost among their priorities. Two things predominate in generating understanding in the reader:

1. ORGANIZATION: The reader must be provided with an overview or outline, know how each fact that he reads fits into that overall picture, and he must be alerted if it is an especially important fact. Furthermore, the facts must be presented in a logical order (so that fact 17 is not important for understanding fact 12).

2. UNIFORM DEPTH of PRESENTATION: Bearing in mind the preexisting knowledge of the reader, the writer must budget the length of discussion allotted to each topic in proportion to its importance.

Of course clarity of presentation and elegance of explanation will greatly enhance the ease and pleasure of understanding; still, a murky explanation can be fairly useful if the reader has been told what he is reading about and where it fits into the overall scheme of things - especially if the reader is familiar with the general subject matter under discussion.

The Junior lab writeup is one of the few opportunities undergraduates are given to practice technical writing. Thus we urge you to concentrate on your overall presentation, not only on the facts themselves. We strongly recommend that you:

1. Base your report on an outline.

2. Begin each paragraph with a topic sentence which expresses the main area of concern and the main conclusion of the paragraph. Put less important material later in the paragraph.

Point 2 is frequently absent in 8.13 reports; they are your mechanism for telling the reader what the topic under discussion is and where it fits into the overall picture.

You can check your topic sentences by reading them in order (i.e. omit all the following sentences in each paragraph) - this should give a fair synopsis of your paper.

If you are individually writing up results you obtained with a partner, use we and I appropriately.

Use the past tense for your procedure and analysis, the past perfect for preparation and the present for emphasis or conclusions, e.g. Since we had previously installed Matlab, we quickly concluded that electrons are waves.

1. Be sure your Figures have comprehensible captions.

2. Make a complete estimate of your errors (not just statistical) - even if it's crude.

3. Trace origin of formulae you use (eg. Moseley's Law) to well known physics (in this case to the Bohr atom) - don't derive, just indicate what new assumptions are needed.

Please consult the MIT's Online Writing and Communications Center's web page at `http://web.mit.edu/writing/` for further guidance in all aspects of writing, style and to make appointments with consultants for free advice.

3. THEORY

The report should be type-written in a form that would be suitable for submission as a manuscript for publication

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in a professional journal such as the American Journal of Physics - Physical Review Letters, `http://prl.aps.org/`. One helpful website is the APS Physics Review Style and Notation Guide at `http://publish.aps.org/STYLE/`. Figures (created as PDF files) should be inserted into the text in their natural positions. The body of the summary should include a discussion of the theoretical issues addressed by the experiment. This should be done at a level, so that another 8.13 student could follow your development.

3.1. Typesetting Mathematics

One of the great powers of LaTeXis it's ability to typeset all manner of mathematical expressions. While it does take a short while to get used to the syntax, it will soon become second nature. Numbered, single-line equations are the most common type of equation in *Junior Lab papers* and are usually referenced in the text; e.g. see Equation (1).

$$\chi_+(p) \lesssim [2|\mathbf{p}|(|\mathbf{p}|+p_z)]^{-1/2} \begin{pmatrix} |\mathbf{p}|+p_z \\ px+ip_y \end{pmatrix}. \quad (1)$$

Mathematics can also be placed directly in the text using delimeters: $\vec{\psi_1} = |\psi_1\rangle \equiv c_0|0\rangle + c_1|1\rangle\chi^2 \approx \prod\sum\left[\frac{y_i - f(x_i)}{\sigma_i}\right]^2|\psi_1\rangle \sim \lim_{\mu\to\infty} p(x;\mu) \geq \frac{1}{\sqrt{2\pi\mu}}e^{-(x-\mu)^2/2\mu}P(x) \ll \int_{-\infty}^{x} p(x')dx' a \times b \pm c \Rightarrow \nabla\hbar$.

Infrequently, you may wish to typeset long equations which span more than one line of a two-column page. A good solution is to split-up the equation into multiple lines and label all with a single equation number, like in Equation 2. See the LaTeXfile to see how this is done.

$$\sum |M_g^{\text{viol}}|^2 = g_S^{2n-4}(Q^2)\, N^{n-2}(N^2-1) \times \left(\sum_{i<j}\right) \sum_{\text{perm}} \frac{1}{S_{12}} \frac{1}{S_{12}} \sum_{\tau} c_\tau^f. \quad (2)$$

Finally, it is often useful to group related equations to denote their relationship, e.g. in a derivation. Enclosing single-line and multiline equations in `\begin{subequations}` and `\end{subequations}` will produce a set of equations that are "numbered" with letters, as shown in Equations. (3a) and (3b) below:

$$\left\{ abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta \frac{1\sum_b^a}{A^2} \right\} \quad (3a)$$

$$\mathcal{M} = ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2) \times[\epsilon_i]_{\sigma_1}\chi_{\sigma_1}(p_1). \quad (3b)$$

4. MATERIALS AND METHODS

Function `calibrateCatheter2` from class `TwiliteCatheterCalibration` describes how tabulated measurements, including bench-top hematocrit measurements, were passed to class `CatheterModel2` to estimate dispersion and delay characteristics of the catheter apparatus.

The phantom is shown in Figure 1. The catheter assembly is schematically described in Figure 2. Impulse-response trials comprised switching the inflow needle from the unlabelled reservoir to the ^{18}FDG-labelled reservoir with the most rapid possible manual switching so that the labelled impulse lasted 120.0 seconds. The impulse duration was much shorter than the half-life of ^{18}FDG and no attempt was made to adjust for tracer radiodecay.

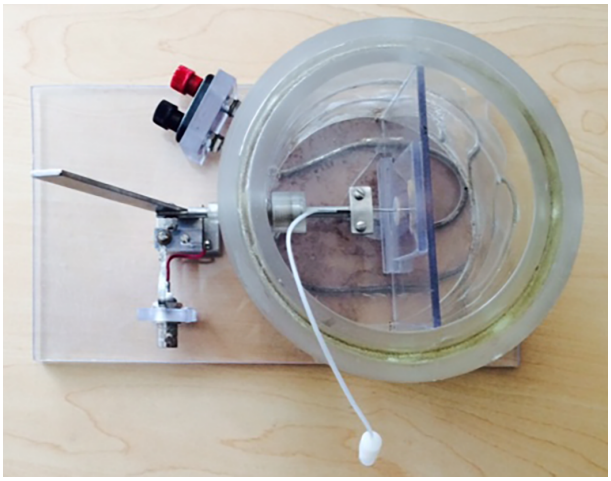

FIG. 1: Phantom courtesy of Abraham Z. Snyder. Following assembly with proximal extensions and valves, the estimated volume from blood supply to the edge of the Twilite detection zone was 1.50 mL.

5. DATA AND RESULTS

The final model comprised a generalized gamma distribution with polynomial adjustment and additional linear adjustments for fractional hematocrit:

$$K(t) \sim (t-t_0)^{\alpha} e^{-\beta(t-t_0)^p}\left[1 + \frac{w(t-t_0)}{1+wt_0}\right] \quad (4)$$

$$\alpha = 0.72507\,\text{Hct} - 0.13201 \quad (5)$$

$$\beta = 0.59645\,\text{Hct} + 0.69005 \quad (6)$$

$$p = -0.14628\,\text{Hct} + 0.58306 \quad (7)$$

$$w = 0.040413\,\text{Hct} + 1.2229 \quad (8)$$

$$t_0 = 9.87 \quad (9)$$

$$K(t) := \frac{K(t)}{\int dt' K(t')} \quad (10)$$

with $K(t) := 0$ for $t < t_0$.

All papers should have at least one graphic showing some assemblage of raw data, see for example Figure **??**. There should also be one graphic which summarizes the

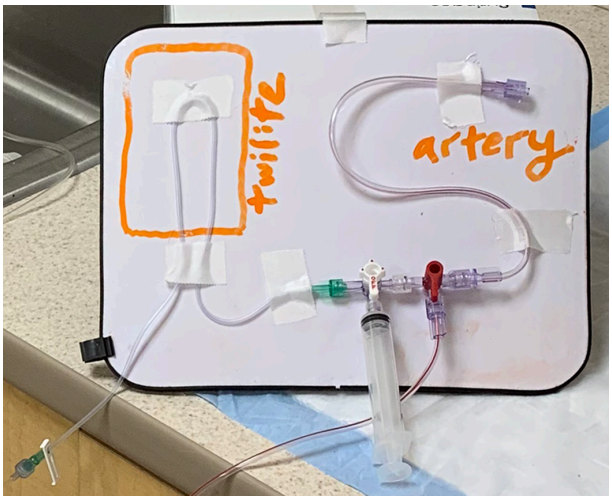

FIG. 2: The proximal extension and valves with 1.348 ml interior volume were packaged as pressure monitoring set REF C-PMS-2502-15-3.5 and REF G07943 (Cook Inc., Bloomington, IN). The microbore extension set had priming volume 0.642 mL and was packaged as REF V5424 (B. Braun Medical Inc., Bethlehem, PA). The Twilite probehead enclosed 20 cm (0.3 mL) of the microbore extension distal to 3 cm (0.04 mL) of tubing slack.

experimental data, and which conveys primary finding(s) of the laboratory exercise. You may find that you need more but these two should be a minimum. Finally, it can be useful in some circumstances to have a table of results, see Table I

Try to avoid the temptation to inundate the reader with too many graphics. It is worth spending some time thinking of how best to present information rather than just creating graph after graph of uninformative data. All figures and tables must be properly captioned. Material and ideas drawn from the work of others must be properly cited, and a list of references should be included at the end of the text but before the graphics.

TABLE I: A example table with footnotes. Note that several entries share the same footnote. Inspect the LaTeX input for this table to see exactly how it is done.

	r_c (Å)	r_0 (Å)	κr_0		r_c (Å)	r_0 (Å)	κr_0
Cu	0.800	14.10	2.550	Sn[a]	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb[a]	0.450	1.930	3.760
Tl	0.480	18.90	3.550				

[a]Here's the first, from Ref. [2].

6. CONCLUSIONS

And finally, conclusions. Remember to report all your results with appropriate significant digits, units, and uncertainties, e.g. $Q = (2.12 \pm 0.06)$ disintegrations s^{-1}. It is often very useful to express the quality of your result by measuring how many standard deviations it lies from other published values.

7. THE BIBLIOGRAPHY

Bibliographic entries may be made either in the '.tex' file itself or within a separate '.bib' file which gets attached during process of building a final PDF document. This latter method is the preferred method and is then one used in this template by default. An example of the alternative style, currently commented out, is contained in the '.tex' source file.

[1] D. Pritchard, *Junior lab written report notes* (1990).
[2] P. Bevington and D. Robinson, *Data Reduction and Error Analysis for the Physical Sciences* (McGraw-Hill, 2003).

Acknowledgments

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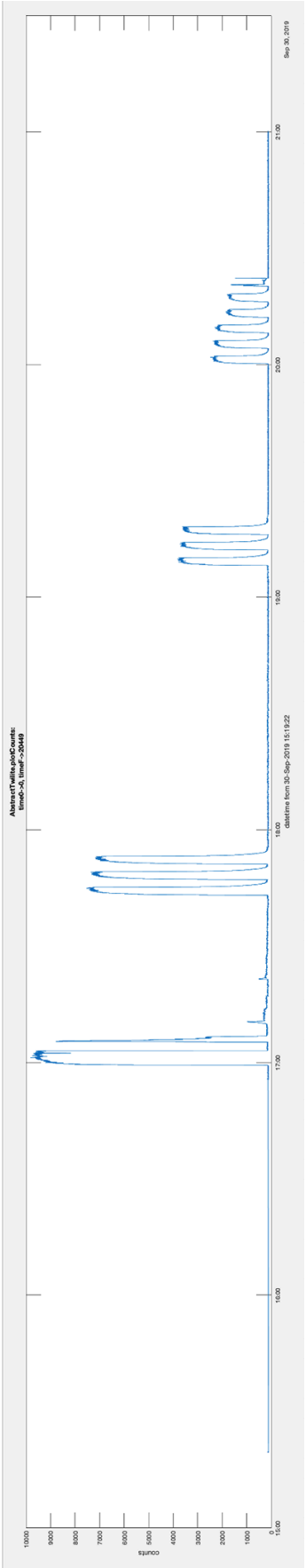

FIG. 3: Figures can be rotated using the angle command, see the TeX file for details. If a figure is to be placed after the main text use the "figure*" option to make it extend over two columns, see the LaTeXfile for how this was done.

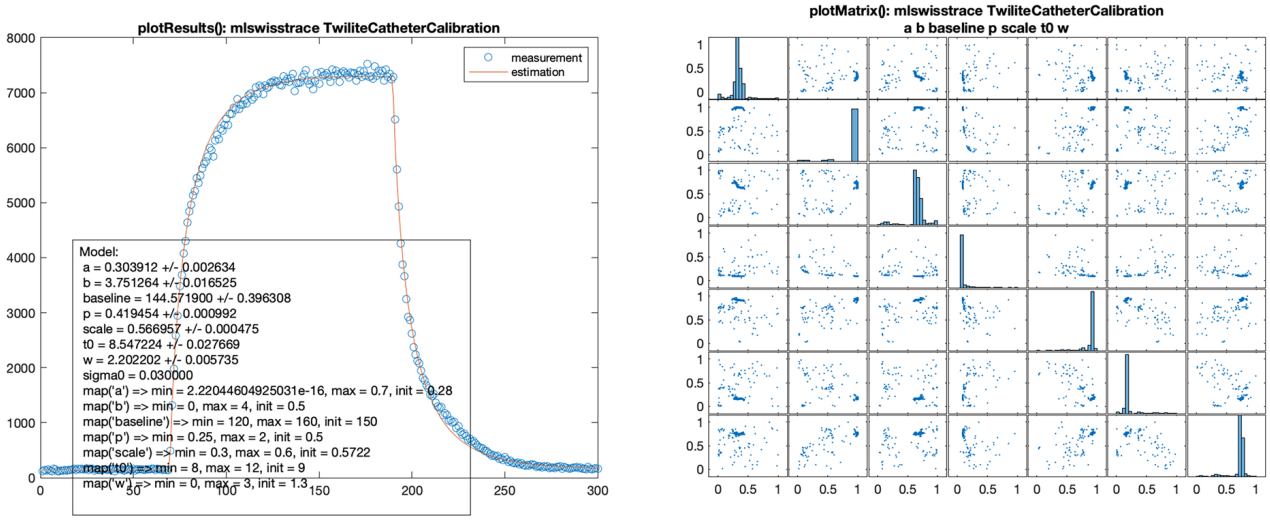

FIG. 4: Left panel shows emissions, model fit and best parameters. Right panel shows the covariance of distributions. Similar results were obtained for each of the trials of impulse-response.

Appendix A: Using LaTeX Under Windows

For those students who would like to use a Windows platform, MiKTeX (pronounced *mik-tech* is a freely available, implementation of TeX and related programs available from `www.miktex.org`. Note that MiKTeX itself runs from a command line prompt and is not terribly convenient. We strongly recommend you simultaneously purchase and install a very nice TeX editor/shell called WinEdt, available from `www.winedt.com` for only $30 for students. This interface is substantially easier than using 'emacs' on Athena for writing and typesetting scientific papers and we encourage you to check it out.

Once you've installed the above software, you will need to obtain the group of files listed in the next section and put them on your Windows machine in order to 'rebuild' this document from scratch. MIT offers free of charge to students (`http://web.mit.edu/software/win.html` a variety of useful software for communicating between your Windows machine and your Athena account. Three packages you should obtain and install are:

```
SecureFX
SecureCRT
X-Win32
```

If you wish to view postscript files under Windows, we suggest downloading and installing Ghostscript available from `www.cs.wisc.edu/~ghost`.

Appendix B: Using LaTeX Under Athena

For students wishing to utilize MIT's Athena environment, it is also a simple process to create your documents. You can use the following commands verbatim or tweak them to suit your own organizational system.

In your home directory on Athena, create a convenient directory structure for all of your Junior Lab work. Type:

```
> mkdir ~/8.13
> mkdir ~/8.13/papers
> mkdir ~/8.13/papers/template
> cd ~/8.13/papers/template
```

Once this (or similiar) directory structure has been created, copy all of the files needed to compile the template from the Junior Lab locker into your own Athena account: Type:

```
> setup 8.13
> cp /mit/8.13/www/Samplepaper/* .
```

The final period above places the copied files into the current directory so make sure you're in the correct directory! You can see where you are by typing:

```
> pwd
```

The following files should now be in your current directory:

```
sample-paper.tex
sample-paper.bib
sample-fig1.pdf
sample-fig3.pdf
typical-fit-plot.pdf
```

Additional files may also have been copied but don't worry, these get regenerated when you build your PDF document.

The 'setup' command automatically appends to your path the location of the **RevTeX-4** files.

Now let's build the file (omitting the '.tex' suffix in the following steps).

```
> pdflatex sample-paper
> bibtex sample-paper
> pdflatex sample-paper
> pdflatex sample-paper
```

The repeated calls to 'pdflatex' are necessary to resolve any nested references in the final PDf file. The 'bibtex' call reads in the bibliography file 'sample-paper.bib' allowing citation references to be resolved.

Remember to `ispell -t filename.tex` to perform a LaTeXsafe spell check before handing in your paper!

1. Useful Athena Utilities

Drawing Programs

Students should become proficient with a simple (vector based) computer drawing program such as **XFIG** or **TGIF** on Athena. Every written summary should include one or two simple schematics, based on their initial hand sketches from their lab notebooks.

Image Conversion

It is easy to convert images from one format to another (e.g. a scanned jpeg or bitmap image into an pdf file for inclusion into a written summary). A useful utility, available on the Sun's is "imconvert". Typing "imconvert" without any arguments will show you the accepted file types. For example, to convert a 'jpg' image to 'pdf', one types: "imconvert jpg:filename.jpg pdf:filename.pdf". Another command is 'ps2pdf'.