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Appendix

Causal Language Definition Development

The AMA defines causal language as any statement that says or implies one variable causes (i.e., to have an effect on) another.

In order to develop the evaluative criteria for what represented causal language for this commentary, two authors reviewed the American Medical Association Manual of Style 10th and 11th editions[1,2,4,5], the *Journal of the American Medical Association* "Instructions for Authors"[6], prior academic work on causal language[7–10], and online information related to causal language in academic research[3,11].

They then reviewed 125 randomly selected articles from the studied journals published during the years 2014-2015 (before the study period) to work through the criteria for what is (and is not) causal language, as well as to identify potential edge cases. The authors labeled the subset of papers that they felt were debatable, as well as the even smaller number of papers they disagreed on. They then met with the senior author, and all three authors deliberated and finalized our criteria for causal language that all authors agreed on.

With the finalized criteria, the two original authors then reviewed approximately 50 additional articles from before the study period to ensure consistency in the criteria.

We then applied the solidified criteria to the articles included in the study (i.e., the 400 random articles from 2016-2019) as per the Methods section.

While the majority of examples used constructs that were clearly causal constructs as in Tables 1 and 2, there were three constructs that were more debatable. We acknowledge that others may "draw the line in the sand" differently than we did; we describe them here for the sake of engendering discussion and transparency.

1.) **Statements that "X Have Y" or other generalized claims made in the present tense were considered causal.** For example, the title "Dual-mobility THA Prostheses Have Worse Outcomes Than Other Designs." This is a generalized statement about a group of hip replacements. It implies the dual-mobility implants are responsible for causing worse outcomes, meeting the definition of causal language. This is different than *describing* a fact about these patients. Indeed, patients with these prostheses may very well have **had** worse outcomes in the authors' study. However, this single observational study cannot determine whether dual-mobility implants **have** worse outcomes writ

large—the findings could be entirely unique to their cohort (e.g., a difference in surgeons who use these implants or in the patients they are used for). The only way a single study could determine that patients with X **Have** Y is either for X to cause Y or for X to be correlated with a confounding factor that causes Y 100% of the time. The former scenario cannot be ascertained from observational data. The latter scenario is implausible, and likely could not be concluded from a single study; if it could, then the study should report that second, causal factor rather than the spuriously correlated one reported. Consistent with this judgement, we could not readily identify any recent publication in the *JAMA* family of journals (who reliably enforce causal language policies) with such a structure. In reviewing the literature, we found that generalized statements in the present tense generally implied causality, whereas similar statements in the past tense were typically descriptive statement of fact about a particular study cohort. While some readers may view this sort of generalized present-tense phrasing as overgeneralization rather than misuse of causal language, we considered these examples to be misuse due to the clear implication that the independent variable mentioned causes/effects the outcome. In this case, the title could be easily and more accurately rewritten as: "Dual-mobility THA Prostheses are Associated with Worse Outcomes Than Other Designs" or "Dual-mobility THA Prostheses **Had** Worse Outcomes Than Other Designs in Cohort of XYZ Patients."

2.) **Statements of "Decreased Y with X" were considered causal.** For example, the title "Decreased Length of Stay with Use of Tranexamic Acid." While some might argue this is descriptive, we considered such examples causal for multiple reasons. First, we believed this title clearly implies tranexamic acid is having an effect on length of stay, meeting the definition of causal language. Second, "with" implies this single factor is responsible for (i.e., causing) this outcome. There is no acknowledgement that some other factor could have been causing this result—yet, this same theoretical study comparing patients over an extended time period during which the use of TXA increased could have been titled "Decreased Length of Stay with the Passage of Time." Association—meaning a statistically significant relationship between two variables in which one does not necessarily cause the other[4]—does not imply a causal role, and would be more accurate in our opinion. For example, "Use of Tranexamic Acid is Associated with Decreased Length of Stay" is factually accurate without the possibility of misinterpretation. The title inherently acknowledges that the results might have been due to the TXA, or they might have been due to some other factor, which is all non-randomized studies can definitively show.

3.) **Statements of "Predictor"/"Predictive" and "Risk Factor" were considered non-causal**. There is also debate about the proper use of the terms, "predictor"/"predictive" and "risk factor." One variable can predict another variable without being responsible for causing it. For example, stained teeth and fingernails may be predictors of lung cancer vis-à-vis the causal factor of smoking. Similarly, something can be a risk factor without

being a *causal* risk factor; these non-causal risk factors are sometimes referred to as risk markers[36]. Therefore, given that the purpose of this piece was to assess causal language specifically, these terms were not considered causal.

Again, we provide these examples for completeness and transparency. We do not purport that our definitions of causal language are the only possible definitions. We further acknowledge that various journals and authors, depending on the context, may feel differently about certain aspects of these classifications of causal and non-causal language, and there is room for reasonable minds to disagree at these edge cases.

Therefore, the rates of misuse of causal language that we calculate should not be considered "the" rates. With even stricter definitions for what is causal language, the inclusion of case series, or the inclusion of "risk factor" as causal terms, the incidence of causal language could have been higher than what we report. On the other hand, with looser definitions for causal language, such as claiming that generalized statements in the present tense ("X have Y" or that "adjective+X with Y") do not imply that X has an effect on Y (i.e., are not causal), then the incidence of causal language could be lower than what we report. Our estimates reflect the specific assumptions we made and should be viewed as such.

Nonetheless, the vast majority of examples of misused causal language that we uncovered did not fall in either of the above buckets. Indeed, regardless of one's stance on each of these issues, it is fair to say that *many* articles in orthopaedics misuse causal language, which we hope will motivate a broader discussion of the use of language in orthopaedics research.

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