Calculating DIGEST Scores in R

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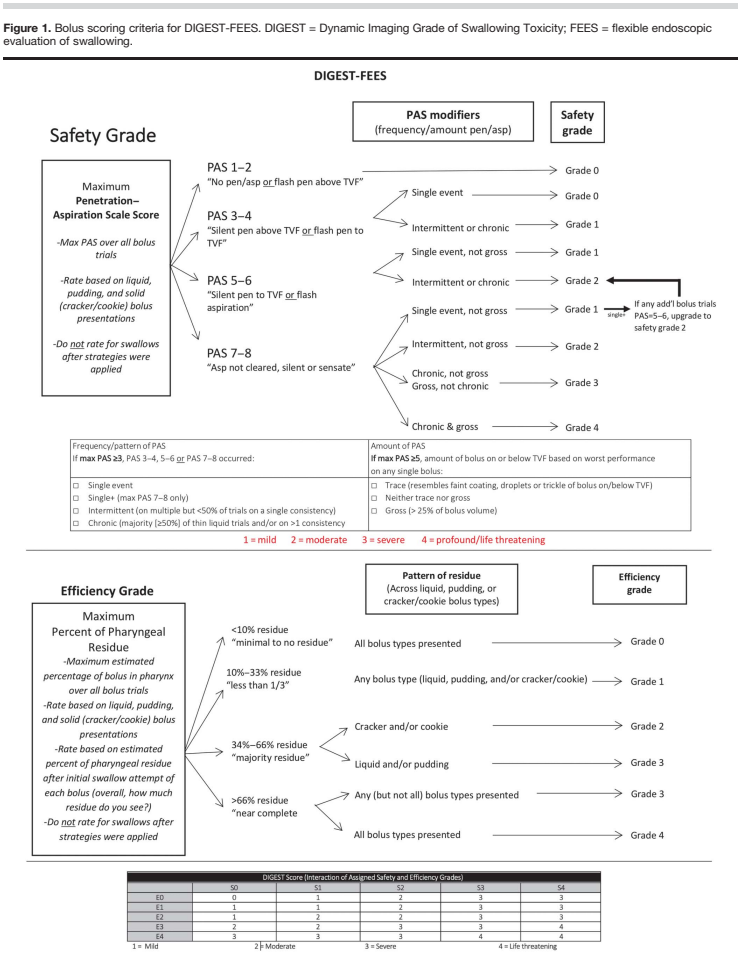
Background

The Dynamic Imaging Grade of Swallowing Toxicity (DIGEST) is a method to grade the severity of pharyngeal swallowing impairment. The scale can be used with either videofluoroscopic swallowing studies (Hutcheson et al., 2016; 2022) or flexible endoscopic evaluations of swallowing (i.e., DIGEST-FEES; Starmer et al., 2021). DIGEST aligns with the Common Terminology Criteria for Adverse Events (CTCAE) commonly employed during clinical trials to grade the severity of cancer toxicity (Grade 1 = mild, 2 = moderate, 3 = severe, 4 = life threatening). DIGEST evaluates the frequency and severity of airway invasion and pharyngeal residue, resulting in grades for swallowing safety and efficiency impairments. Grades from these two domains are used to derive an overall severity grade (Grade 1 = no dysphagia, 2 = moderate, 3 = severe, 4 = profound/life threatening).

Figure 1. Bolus scoring criteria for DIGEST-FEES. DIGEST = Dynamic Imaging Grade of Swallowing Toxicity; FEES = flexible endoscopic evaluation of swallowing.



Our goal in this vignette is to describe how to use an R function to automatically calculate safety, efficiency, and total DIGEST-FEES scores.

Setting Up Your Data

First, we need to load the necessary R packages.

```
library(tidyverse) # data wrangling
library(simstudy) # simulate data
set.seed(2022) # reproducibility
```

Next, we will simulate some fake swallowing data that we will use as an example for the function. Below we have simulated 20 participants and can view the variable names.

```
data_frame <- simulate_swallowing_data(
  between_variance = 1,
  sample_size = 20)

head(data_frame)
#> # A tibble: 6 x 6
#> # Groups:   id [2]
#>      id pen_asp vocal_folds_severity_rating subglottis_severity_~1 perce~2 IDDSI
#>   <int>   <dbl>                       <dbl>                   <dbl>   <dbl> <dbl>
#> 1     1       4                          NA                      NA    4.42       0
#> 2     1       6                          NA                      NA    1.51       0
#> 3     1       7                          NA                       0.0390  1.28       0
#> 4     1       7                          NA                      11.5     0.0899     0
#> 5     2       3                          NA                      NA    6.83       0
#> 6     2       3                          NA                      NA    4.17       0
#> # ... with abbreviated variable names 1: subglottis_severity_rating,
#> #   2: percent_pharyngeal_residue
```

You can also import your own data. You can download a csv template here if you'd like.

```
data_frame <- read.csv("your data path here.csv")
```

Once you download the R script from here then import the DIGEST-FEES function into R.

```
source("digest_fees_function.R")
```

Next, we need to specify the variable names from our data set in the function. Below you'll see that my PAS variable was named "pen-asp" and my data was called "data_frame" so we had to specify these in the function. A few other notes:

- IDDSI should be coded numerically according to the IDDSI Framework.
- PAS should be coded numerically ranging from 1 - 8.
- Overall pharyngeal residue, vocal fold residue, and subglottic residue should be coded as a percentage (i.e., ranging from 0 to 100).

```
digest_fees_function(
  data = data_frame,
  id = id,
  IDDSI = IDDSI,
  pas = pen_asp,
  percent_pharyngeal_residue,
  vocal_folds_severity_rating,
  subglottis_severity_rating
)
#> # A tibble: 20 x 6
#> # Groups:   id [20]
#>       id max_pas safety_grade max_residue_score efficiency_grade total_grade
#>    <int>   <dbl>        <dbl>              <dbl>            <dbl>       <dbl>
#>  1     1       7            2               30.5                1           2
#>  2     2       5            2               23.4                1           2
#>  3     3       5            2               33.8                3           3
#>  4     4       5            2               43.3                3           3
#>  5     5       7            2               38.4                3           3
#>  6     6       5            2               22.9                1           2
#>  7     7       5            2               37.2                3           3
#>  8     8       5            2               74.3                3           3
#>  9     9       6            1               25.7                1           1
#> 10    10       7            2               35.9                3           3
#> 11    11       7            2               43.6                3           3
#> 12    12       7            2               26.7                1           2
#> 13    13       6            1               40.5                3           2
#> 14    14       6            1               25.4                1           1
#> 15    15       7            3               44.2                3           3
#> 16    16       6            1               32.9                1           1
#> 17    17       6            1               36.1                3           2
#> 18    18       7            2               32.6                1           2
#> 19    19       7            2               46.4                3           3
#> 20    20       7            2               22.1                1           2
```

The function provides

- The participant's ID
- Maximum PAS score from the protocol
- Maximum amount of overall pharyngeal residue
- DIGEST-FEES safety grade
- DIGEST-FEES efficiency grade
- DIGEST-FEES total grade

APPENDIX

Here is the function in its totality.

```
digest_fees_function <- function(data, # put data frame name here
                          id, # put name of id grouping variable here
                          IDDSI, # put name of consistency variable here
                          pas, # put name of PAS outcome variable here
```

```
                          percent_pharyngeal_residue, # put name of % pharyngeal residue score here
                          vocal_folds_severity_rating, # put name of VF severity rating here
                          subglottis_severity_rating # put name of subglottis severity rating here
) {

  ### Calculate SAFETY Grade
  data_x <- {{data}} |>
    group_by(id, {{IDDSI}}) |>
    summarise(num_trials = n()) # calculate # of trials for each consistency

  x <- inner_join(data, data_x) # join # of trials summary with full data set

  x2 <- x |>
    group_by(id, {{IDDSI}}, .drop = F) |> # calculate % of PAS for each grouping by consistency
    mutate(perc_3_4 = sum({{pas}} == 3 | {{pas}} == 4, na.rm = T)/num_trials,
           perc_5_6 = sum({{pas}} == 3 | {{pas}} == 4, na.rm = T)/num_trials,
           perc_7_8 = sum({{pas}} == 3 | {{pas}} == 4, na.rm = T)/num_trials) |>
    group_by(id) |>
    mutate(binary_airway_invasion = case_when({{pas}} > 2 ~ 1, # counts number of PAS > 2 events per pa
                                              {{pas}} <= 2 ~ 0),
           max_pas = max({{pas}}, na.rm = T), # max PAS
           freq_3_4 = sum({{pas}} == 3 | {{pas}} == 4, na.rm = T), # overall frequencies for PAS 3 & 4
           freq_5_6 = sum({{pas}} == 5 | {{pas}} == 6, na.rm = T), # overall frequencies for PAS 5 & 6
           freq_7_8 = sum({{pas}} == 7 | {{pas}} == 8, na.rm = T)) # overall frequency of PAS 7 or 8

  x3 <- x2 |> # calculates airway invasion across multiple consistencies
    group_by(id, {{IDDSI}}) |>
    mutate(freq_airway_invasion = sum(binary_airway_invasion, na.rm = T),
           airway_invasion_by_consistency = case_when(freq_airway_invasion >= 1 ~ 1,
                                                      freq_airway_invasion < 1 ~ 0)
    ) |>
    dplyr::slice(1) |>
    group_by(id) |>
    summarise(sum(airway_invasion_by_consistency, na.rm = T)) |>
    mutate(airway_invasion_multiple_consistencies = case_when(
      `sum(airway_invasion_by_consistency, na.rm = T)` > 1 ~ "yes",
      `sum(airway_invasion_by_consistency, na.rm = T)` <= 1 ~ "no")) |>
    dplyr::select(id, airway_invasion_multiple_consistencies)

  x4 <- inner_join(x2, x3)

  x5 <- x4 |> # summary info on whether someone had intermittent or chronic frequency on at least 1 con
    group_by(id, {{IDDSI}}) |>
    dplyr::slice(1) |>
    group_by(id) |>
    mutate(pas_3_4_chronic_pre = case_when(perc_3_4 < 50 ~ 0, # count number of times >= 50% events
                                           perc_3_4 >= 50 ~ 1),
           pas_5_6_chronic_pre = case_when(perc_5_6 < 50 ~ 0,
                                           perc_5_6 >= 50 ~ 1),
           pas_7_8_chronic_pre = case_when(perc_7_8 < 50 ~ 0,
                                           perc_7_8 >= 50 ~ 1),
           pas_3_4_chronic_pre_sum = sum(pas_3_4_chronic_pre, na.rm = T), # add up freq of these events
           pas_5_6_chronic_pre_sum = sum(pas_5_6_chronic_pre, na.rm = T),
```

```
          pas_7_8_chronic_pre_sum = sum(pas_7_8_chronic_pre, na.rm = T)
  ) |>
  dplyr::slice(1) |>
  mutate(pas_3_4_chronic = case_when(pas_3_4_chronic_pre_sum <= 1 ~ "intermittent",
                                     pas_3_4_chronic_pre_sum >1 ~ "chronic"),
         pas_5_6_chronic = case_when(pas_5_6_chronic_pre_sum <= 1 ~ "intermittent",
                                     pas_5_6_chronic_pre_sum >1 ~ "chronic"),
         pas_7_8_chronic = case_when(pas_7_8_chronic_pre_sum <= 1 ~ "intermittent",
                                     pas_7_8_chronic_pre_sum >1 ~ "chronic")
  ) |>
  dplyr::select(id, pas_3_4_chronic, pas_5_6_chronic, pas_7_8_chronic)

x6 <- inner_join(x4, x5)

df_safety <- x6 |>
  dplyr::select(id, {{pas}}, max_pas, {{vocal_folds_severity_rating}},
                {{subglottis_severity_rating}}, freq_3_4, freq_5_6, freq_7_8,
                airway_invasion_multiple_consistencies, pas_3_4_chronic,
                pas_5_6_chronic, pas_7_8_chronic) |>
  drop_na({{pas}}) |>
  group_by(id) |>
  top_n(1, {{pas}}) |>  # keep rows based on max PAS
  mutate( # calculate max values for VF and subglottis for when > 2 trials with same max PAS score
    vocal_folds_severity_rating_max = case_when(
      max_pas >= 5 | max_pas <= 6 ~ max({{vocal_folds_severity_rating}})),
    subglottis_severity_rating_max = case_when(max_pas >= 7 | max_pas <= 8 ~ max({{subglottis_severity
  ) |>
  dplyr::slice(1) |>
  mutate(safety_grade = case_when(
    max_pas == 1 | max_pas == 2 ~ 0,
    freq_3_4 == 1 & max_pas == 3 | max_pas == 4 ~ 0, # PAS 3-4, single event
    freq_3_4 > 1 & max_pas == 3 | max_pas == 4 ~ 1, # PAS 3-4, multiple events
    freq_5_6 == 1 & vocal_folds_severity_rating_max <= 25 & max_pas == 5 | max_pas == 6 ~ 1, # PAS 5-
    freq_5_6 == 1 & vocal_folds_severity_rating_max > 25 & max_pas == 5 | max_pas == 6 ~ 2, # PAS 5-6
    freq_5_6 > 1 & max_pas == 5 | max_pas == 6 ~ 2, # PAS 5-6, multiple events
    freq_7_8 == 1 & subglottis_severity_rating_max <= 25 & freq_5_6 < 1 & max_pas == 7 | max_pas == 8
    freq_7_8 == 1 & subglottis_severity_rating_max <= 25 & freq_5_6 >= 1 & max_pas == 7 | max_pas == 8
    freq_7_8 > 1 & pas_7_8_chronic == "intermittent" & subglottis_severity_rating_max <= 25 & max_pas
    freq_7_8 > 1 & pas_7_8_chronic == "chronic" | airway_invasion_multiple_consistencies == "yes" & su
    freq_7_8 >= 1 & pas_7_8_chronic == "intermittent" & subglottis_severity_rating_max > 25 & max_pas
    freq_7_8 > 1 & pas_7_8_chronic == "chronic" | airway_invasion_multiple_consistencies == "yes" & su
  )
  ) |>
  select(id, max_pas, safety_grade)

### Calculate EFFICIENCY Grade
df1 <- {{data}} |> # calculate efficiency groupings by consistency
  group_by(id) |>
  mutate(max_residue_score = max({{percent_pharyngeal_residue}})
  ) |>
  group_by(id, {{IDDSI}}) |>
  mutate(efficiency_group_1 = case_when({{percent_pharyngeal_residue}} < .10 ~ 1),
         efficiency_group_2 = case_when({{percent_pharyngeal_residue}} >= .10 & {{percent_pharyngeal_
```

```
          efficiency_group_3 = case_when({{percent_pharyngeal_residue}} >= .34 & {{percent_pharyngeal_
          efficiency_group_4 = case_when({{percent_pharyngeal_residue}} > .66 ~ 1),
          efficiency_group_1_freq = sum(efficiency_group_1, na.rm = T),
          efficiency_group_2_freq = sum(efficiency_group_2, na.rm = T),
          efficiency_group_3_freq = sum(efficiency_group_3, na.rm = T),
          efficiency_group_4_freq = sum(efficiency_group_4, na.rm = T),
  ) |>
  dplyr::slice(1) |>
  dplyr::select(id, {{IDDSI}}, max_residue_score, efficiency_group_1_freq,
                efficiency_group_2_freq, efficiency_group_3_freq, efficiency_group_4_freq)

df2 <- df1 |> # count number of consistencies administered per participant
  group_by(id) |>
  summarise(number_of_consistencies = n())

df3 <- inner_join(df1, df2)

df_efficiency <- df3 |>
  group_by(id) |>
  mutate(efficiency_grade = case_when(max_residue_score < 10 ~ 0,
                                      max_residue_score >= 10 & max_residue_score <= 33 ~ 1,
                                      {{IDDSI}} == 7 & max_residue_score >= 34 & max_residue_score <=
                                      {{IDDSI}} == 0 | {{IDDSI}} == 4 & max_residue_score >= 34 & max_
                                      efficiency_group_4_freq/number_of_consistencies > 0 ~ 3,
                                      efficiency_group_4_freq/number_of_consistencies == 1 ~ 4)
  ) |>
  dplyr::slice(1) |>
  dplyr::select(id, max_residue_score, efficiency_grade)

# Combine safety and efficiency grades into 1 data set
data_dfs <- inner_join(df_safety, df_efficiency)

### CALCULATE TOTAL DIGEST Scores
data_dfs |>
  group_by(id) |>
  mutate(total_grade = case_when(safety_grade == 0 & efficiency_grade == 0 ~ 0,
                                 safety_grade == 0 & efficiency_grade == 1 ~ 1,
                                 safety_grade == 0 & efficiency_grade == 2 ~ 1,
                                 safety_grade == 0 & efficiency_grade == 3 ~ 2,
                                 safety_grade == 0 & efficiency_grade == 4 ~ 3,
                                 safety_grade == 1 & efficiency_grade == 0 ~ 1,
                                 safety_grade == 1 & efficiency_grade == 1 ~ 1,
                                 safety_grade == 1 & efficiency_grade == 2 ~ 2,
                                 safety_grade == 1 & efficiency_grade == 3 ~ 2,
                                 safety_grade == 1 & efficiency_grade == 4 ~ 3,
                                 safety_grade == 2 & efficiency_grade == 0 ~ 2,
                                 safety_grade == 2 & efficiency_grade == 1 ~ 2,
                                 safety_grade == 2 & efficiency_grade == 2 ~ 2,
                                 safety_grade == 2 & efficiency_grade == 3 ~ 3,
                                 safety_grade == 2 & efficiency_grade == 4 ~ 3,
                                 safety_grade == 3 & efficiency_grade == 0 ~ 3,
                                 safety_grade == 3 & efficiency_grade == 1 ~ 3,
                                 safety_grade == 3 & efficiency_grade == 2 ~ 3,
```

```
                                    safety_grade == 3 & efficiency_grade == 3 ~ 3,
                                    safety_grade == 3 & efficiency_grade == 4 ~ 4,
                                    safety_grade == 4 & efficiency_grade == 0 ~ 3,
                                    safety_grade == 4 & efficiency_grade == 1 ~ 3,
                                    safety_grade == 4 & efficiency_grade == 2 ~ 3,
                                    safety_grade == 4 & efficiency_grade == 3 ~ 4,
                                    safety_grade == 4 & efficiency_grade == 4 ~ 4))
}
```