Contents

R code for eGFR calculation

```
###Function egfr.calc
#### Version 2023/06/13
### Purpose: To calculate eGFR given urine markers (creatinine, cystatin C, B2M and/or BTP) and demographic factors based on CKD-EPI equations (Levey et al Annals 2009, Inker et al NEJM 2012, Inker et al NEJM 2021)

###Input:
#  data.in: name of the input data
# id: subject ID
# scr, cys, b2m, btp: variables in data_in indicating scr, cys, b2m and/or btp levels; empty variable(s) is(are) created if not available
# age: variable in data_in indicating age (in years)
# female: variable in data_in indicating  female (1) or male (0)
# black: variable in data_in indicating black (1) or non-black (0) race group
# height: variable in data_in indicating height (in meters)
# digits: defines the number of decimal places to be rounded after calculation
# merge: logical, if TRUE the output would be original dataset with calculated eGFR appended; otherwise only outputs the subject ID and calculated eGFR
# export: could be an output directory and file name where the output data frame is exported; only csv output is supported


### Output:
# A data frame that could duplicate data.in and append the calculated eGFR variables
# Equation names (the suffix indicates the demographic variables used of age, sex or race)
#egfr_cr09_asr:  2009 CKD-EPI Creatinine, Levey et al Annals 2009
#egfr_cr21_as:   2021 CKD-EPI Creatinine, Inker NEJM 2021
#egfr_cys12_as: 2012 CKD-EPI Cystatin C Inker NEJM 2012
#egfr_cc12_asr: 2012 CKD-EPI Creatinine-Cystatin C Inker NEJM 2012
#egfr_cc21_as:   2021 CKD-EPI Creatinine-Cystatin C Inker NEJM 2021
#egfr3m_scrcysb2m_as: 2020 Creatinine-Cystatin C-B2M Inker AJKD 2021
#egfr3m_scrcysbtp_as: 2020 Creatinine-Cystatin C-BTP Inker AJKD 2021
#egfr3m_cysb2mbtp_as: 2020 Cystatin C-B2M-BTP Inker AJKD 2021
#egfr4m_as: 2020 Creatinine-Cystatin C-B2M-BTP Inker AJKD 2021
#egfrU25_: U25 equations (creatinine, cystatin C and average)
#egfr_ekfc_: EKFC equations (creatinine/cystatin C)
#egfr_tplnt: transplant equation (creatinine)
# Note that if any input marker is not available, the eGFR based on the respective marker(s) would not be calculated
```

```
egfr.calc = function(data.in, id, age, female, black, height=NULL,
                scr=NULL, cys=NULL, b2m=NULL, btp=NULL, digits=0, merge=T, export=NULL){
 if(!is.numeric(age) || any((female %in% c(0,1))==F) || any((black %in% c(0,1))==F)){
   stop("Invalid input; possible reasons:\n1) \"Age\" variable is not numeric\n2) Unexpected and/or
invalid value(s) in \"female\" or \"black\" variables")}

 #Coefficient setup
 coefftbl_1=data.frame(eq=c("cr09_asr"), mu=c(141),
                  cr_1f=c(-0.329), cr_1m=c(-0.411), cr_2=c(-1.209),
                  cys_1=c(0), cys_2=c(0),
                  btp_1=c(0), btp_2=c(0),
                  fac_age=c(0.993), fac_f=c(1.018), fac_b=c(1.159) )
 coefftbl_1=rbind(coefftbl_1,list("cys12_as", 133, 0, 0, 0, -0.499, -1.328, 0, 0, 0.996, 0.932, 0))
 coefftbl_1=rbind(coefftbl_1,list("cc12_asr", 135, -0.248, -0.207, -0.601, -0.375, -0.711, 0, 0, 0.995,
0.969, 1.080))
 coefftbl_1=rbind(coefftbl_1,list("cr21_as", 142, -0.241, -0.302, -1.200, 0, 0, 0, 0, 0.9938, 1.012, 0))
 coefftbl_1=rbind(coefftbl_1,list("cc21_as", 135, -0.219, -0.144, -0.544, -0.323, -0.778, 0, 0, 0.9961,
0.963, 0))

 egfr_cr09_asr=NULL; egfr_cys12_as=NULL; egfr_cc12_asr=NULL; egfr_cr21_as=NULL;
egfr_cc21_as=NULL
 egfr3m_scrcysb2m_as=NULL; egfr3m_scrcysbtp_as=NULL; egfr3m_cysb2mbtp_as=NULL;
egfr4m_as=NULL;


 #Exponentiated equations (as in original publication)
 #Cr Age-sex-race (Levey 2009 Annals)
 if(!is.null(scr)){
  egfr_cr09_asr=unlist(coefftbl_1[coefftbl_1$eq=="cr09_asr","mu"]
                  *sapply(scr/ifelse(female==1, 0.7,0.9), min,
1)^coefftbl_1[coefftbl_1$eq=="cr09_asr",ifelse(female==1,"cr_1f","cr_1m")]
                  *sapply(scr/ifelse(female==1, 0.7,0.9), max,
1)^coefftbl_1[coefftbl_1$eq=="cr09_asr","cr_2"]
                  *coefftbl_1[coefftbl_1$eq=="cr09_asr","fac_age"]^age
                  *ifelse(female==1, coefftbl_1[coefftbl_1$eq=="cr09_asr","fac_f"],1)
                  *ifelse(black==1, coefftbl_1[coefftbl_1$eq=="cr09_asr","fac_b"],1) )
 }
 #Cr Age-sex (Inker 2021 NEJM)
 if(!is.null(scr)){
  egfr_cr21_as=unlist(coefftbl_1[coefftbl_1$eq=="cr21_as","mu"]
                 *sapply(scr/ifelse(female==1, 0.7,0.9), min,
1)^coefftbl_1[coefftbl_1$eq=="cr21_as",ifelse(female==1,"cr_1f","cr_1m")]
                  *sapply(scr/ifelse(female==1, 0.7,0.9), max,
1)^coefftbl_1[coefftbl_1$eq=="cr21_as","cr_2"]
                  *coefftbl_1[coefftbl_1$eq=="cr21_as","fac_age"]^age
                  *ifelse(female==1, coefftbl_1[coefftbl_1$eq=="cr21_as","fac_f"],1) )
 }
```

```
 #Cys Age-sex (Inker 2012 NEJM)
 if(!is.null(cys)){
  egfr_cys12_as=unlist(coefftbl_1[coefftbl_1$eq=="cys12_as","mu"]
                *sapply(cys/0.8, min, 1)^coefftbl_1[coefftbl_1$eq=="cys12_as","cys_1"]
                *sapply(cys/0.8, max, 1)^coefftbl_1[coefftbl_1$eq=="cys12_as","cys_2"]
                *coefftbl_1[coefftbl_1$eq=="cys12_as","fac_age"]^age
                *ifelse(female==1, coefftbl_1[coefftbl_1$eq=="cys12_as","fac_f"],1) )
 }
 #Cr-cys Age-sex-race (Inker 2012 NEJM)
 if(!is.null(scr)&!is.null(cys)){
  egfr_cc12_asr=unlist(coefftbl_1[coefftbl_1$eq=="cc12_asr","mu"]
                *sapply(scr/ifelse(female==1, 0.7,0.9), min,
1)^coefftbl_1[coefftbl_1$eq=="cc12_asr",ifelse(female==1,"cr_1f","cr_1m")]
                *sapply(scr/ifelse(female==1, 0.7,0.9), max,
1)^coefftbl_1[coefftbl_1$eq=="cc12_asr","cr_2"]
                *sapply(cys/0.8, min, 1)^coefftbl_1[coefftbl_1$eq=="cc12_asr","cys_1"]
                *sapply(cys/0.8, max, 1)^coefftbl_1[coefftbl_1$eq=="cc12_asr","cys_2"]
                *coefftbl_1[coefftbl_1$eq=="cc12_asr","fac_age"]^age
                *ifelse(female==1, coefftbl_1[coefftbl_1$eq=="cc12_asr","fac_f"],1)
                *ifelse(black==1, coefftbl_1[coefftbl_1$eq=="cc12_asr","fac_b"],1) )
 }
 #Cr-cys Age-sex (Inker 2021 NEJM)
 if(!is.null(scr)&!is.null(cys)){
  egfr_cc21_as=unlist(coefftbl_1[coefftbl_1$eq=="cc21_as","mu"]
                *sapply(scr/ifelse(female==1, 0.7,0.9), min,
1)^coefftbl_1[coefftbl_1$eq=="cc21_as",ifelse(female==1,"cr_1f","cr_1m")]
                *sapply(scr/ifelse(female==1, 0.7,0.9), max,
1)^coefftbl_1[coefftbl_1$eq=="cc21_as","cr_2"]
                *sapply(cys/0.8, min, 1)^coefftbl_1[coefftbl_1$eq=="cc21_as","cys_1"]
                *sapply(cys/0.8, max, 1)^coefftbl_1[coefftbl_1$eq=="cc21_as","cys_2"]
                *coefftbl_1[coefftbl_1$eq=="cc21_as","fac_age"]^age
                *ifelse(female==1, coefftbl_1[coefftbl_1$eq=="cc21_as","fac_f"],1) )
 }

 #Scr-cys-B2M 3-marker AS (Inker 2021 AJKD: 2020 Creatinine-Cystatin C-B2M Equation)
 if(!is.null(scr)&!is.null(cys)&!is.null(b2m)){
  egfr3m_scrcysb2m_as=exp(4.913849588 -0.057542983*female -0.003658991*age
                  +ifelse(female==1, ifelse(scr<=0.7, -0.192734414, -0.507357215), ifelse(scr<=0.9, -
0.233821173, -0.507357215))*(log(scr)-log(ifelse(female==1,0.7,0.9)))
                  +ifelse(cys<=0.8, -0.434860516, -0.508049507)*(log(cys)-log(0.8)) -
0.165382497*log(b2m) )
 }
 #Scr-cys-BTP 3-marker AS (Inker 2021 AJKD: 2020 Creatinine-Cystatin C-BTP Equation)
 if(!is.null(scr)&!is.null(cys)&!is.null(btp)){
  egfr3m_scrcysbtp_as=exp(4.836942024 -0.068906753*female -0.00397527*age
                  +ifelse(female==1, ifelse(scr<=0.7, -0.242368992, -0.490505009), ifelse(scr<=0.9, -
0.306793318, -0.490505009))*(log(scr)-log(ifelse(female==1,0.7,0.9)))
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                +ifelse(cys<=0.8, -0.59493920, -0.505001311)*(log(cys)-log(0.8)) +ifelse(btp<=0.6, -
0.005268947, -0.199563102)*(log(btp)-log(0.6)) )
 }
 #Cys-B2M-BTP 3-marker AS (Inker 2021 AJKD)
 if(!is.null(cys)&!is.null(b2m)&!is.null(btp)){
  egfr3m_cysb2mbtp_as=exp(4.78473 -0.08106*female -0.00136*age +ifelse(cys<=0.8, -0.87628, -
0.69654)*(log(cys)-log(0.8))
                +ifelse(btp<=0.6, 0.03763, -0.24332)*(log(btp)-log(0.6)) -0.20539*log(b2m) )
 }
 #Cr-cys-B2M-BTP 4-marker AS (Inker 2021 AJKD)
 if(!is.null(scr)&!is.null(cys)&!is.null(b2m)&!is.null(btp)){
  egfr4m_as=exp(4.87408 -0.06546*female -0.00370*age
          +ifelse(female==1, ifelse(scr<=0.7, -0.24296, -0.47131), ifelse(scr<=0.9, -0.29481, -
0.47131))*(log(scr)-log(ifelse(female==1,0.7,0.9)))
          +ifelse(cys<=0.8, -0.51938, -0.42276)*(log(cys)-log(0.8)) +ifelse(btp<=0.6, -0.00369, -
0.17710)*(log(btp)-log(0.6))
          -0.10324*log(b2m) )
 }

 #U25
 ckidKscr = 39.0 * (1.008^(age-12)) * (female==0 & age<12) +
  39.0 * (1.045^(age-12)) * (female==0 & age>=12 & age<15) +
  39.0 * (1.045^(age-12)) * (female==0 & age>=15 & age<18) +
  50.8 * (female==0 & age>=18) +
  36.1 * (1.008^(age-12)) * (female==1 & age<12) +
  36.1 * (1.023^(age-12)) * (female==1 & age>=12 & age<18)+
  41.4 * (female==1 & age>=18)
 ckidKcys = 87.2 * (1.011^(age-15)) * (female==0 & age<12) +
  87.2 * (1.011^(age-15)) * (female==0 & age>=12 & age<15) +
  87.2 * (0.960^(age-15)) * (female==0 & age>=15 & age<18) +
  77.1 * (female==0 & age>=18) +
  79.9 * (1.004^(age-12)) * (female==1 & age<12) +
  79.9 * (0.974^(age-12)) * (female==1 & age>=12 & age<18) +
  68.3 * (female==1 & age>=18)

 egfrU25_scr=NULL; egfrU25_cys=NULL; egfrU25_avg=NULL;
 if(!is.null(scr) & !is.null(height)){
  egfrU25_scr = ckidKscr * height / scr
 }
 if(!is.null(cys)){
  egfrU25_cys = ckidKcys * (1 / cys)
 }
 if(!is.null(scr) & !is.null(cys) &!is.null(height)){
  egfrU25_avg = (egfrU25_scr + egfrU25_cys)/2;
 }

 #EKFC
 egfr_ekfc_scr=NULL; egfr_ekfc_cys=NULL;
```

```
  q_ekfc_scr=ifelse(age>25,
                ifelse(female==1,0.7,0.9),
                ifelse(female==1,
                     1/88.4*exp(3.080+0.177*age-0.223*log(age)-
0.00596*age*age+0.0000686*age*age*age),
                     1/88.4*exp(3.200+0.259*age-0.543*log(age)-
0.00763*age*age+0.0000790*age*age*age)))
  q_ekfc_cys=ifelse(age>50,0.83+0.005*(age-50),0.83)
  if(!is.null(scr)){
    egfr_ekfc_scr=107.3*(scr/q_ekfc_scr)^ifelse(scr/q_ekfc_scr<1,-0.322,-
1.132)*ifelse(age>40,0.990^(age-40),1)
  }
  if(!is.null(cys)){
    egfr_ekfc_cys=107.3*(cys/q_ekfc_cys)^ifelse(cys/q_ekfc_cys<1,-0.322,-
1.132)*ifelse(age>40,0.990^(age-40),1)
  }

  #Transplant
  egfr_tplnt=NULL
  if(!is.null(scr)){
    egfr_tplnt=exp( 4.42755 -0.82305*log(scr) -0.01243*scr*scr -0.00551*age +0.18065*(1-female) )
  }

  #Final compilation
  data.out =
data.frame(id=as.character(id),cbind(egfr_cr09_asr,egfr_cr21_as,egfr_cys12_as,egfr_cc12_asr,egfr_cc21
_as,

egfr3m_scrcysb2m_as,egfr3m_scrcysbtp_as,egfr3m_cysb2mbtp_as,egfr4m_as,

egfrU25_scr,egfrU25_cys,egfrU25_avg,egfr_ekfc_scr,egfr_ekfc_cys,egfr_tplnt))
  if(!is.na(digits)){(data.out[,-1]=round(data.out[,-1],digits))}
  if(merge==T){data.out=cbind(data.in,data.out[,-1])}
  if(is.character(export) & length(export)==1){write.csv(data.out,export,row.names=F)}
  return(data.out)
}

#For demonstration
# d.demo=read.csv("G:/data_in.csv")
# d.demo.out=egfr.calc(d.demo,d.demo$id_demo,d.demo$age,d.demo$female,d.demo$black,
#                  scr=d.demo$creatinine,cys=d.demo$cystatinc,b2m=d.demo$b2m,btp=d.demo$btp,
#                  export="G:/data_out.csv")
#
# d.demo2=read.csv("check_u25_calculations.csv")
# d.demo2.out=egfr.calc(d.demo2,d.demo2$testid,d.demo2$age,d.demo2$female,0,d.demo2$ht_m,
#                   scr=d.demo2$scr,cys=d.demo2$cyc_ifcc)[,c(1:9,15:17)]
# write.csv(d.demo2.out,"check_u25_calc_jm.csv",row.names=F)
```

SAS code for eGFR calculation

```
/*
Macro egfr_calc_ckdepi
 Version 01 Oct 2021
Purpose: To calculate eGFR given urine markers (creatinine, cystatin
C, B2M and/or BTP) and demographic factors based on CKD-EPI equations
(Levey et al Annals 2009, Inker et al NEJM 2012, Inker et al NEJM
2021)

Input:
 data_in: name of the input data
scr, cys, b2m, btp: variables in data_in indicating scr, cys, b2m
and/or btp levels; empty variable(s) is(are) created if not available
age: variable in data_in indicating age (in years)
female: variable in data_in indicating  female (1) or male (0)
black: variable in data_in indicating black (1) or non-black (0) race
group
height: variable in data_in indicating height (in meters)
name_out: name of the output dataset


Output:
 A SAS dataset egfr_out that copies data_in and append the calculated
eGFR variables
 Equation names (the suffix indicates the demographic variables used
of age, sex or race)
egfrcr:  2009 CKD-EPI Creatinine, Levey et al Annals 2009
egfr_cr21_as:   2021 CKD-EPI Creatinine, Inker NEJM 2021
egfrcys: 2012 CKD-EPI Cystatin C Inker NEJM 2012
egfrcc: 2012 CKD-EPI Creatinine-Cystatin C Inker NEJM 2012
egfr_cc21_as:   2021 CKD-EPI Creatinine-Cystatin C Inker NEJM 2021
egfr3m_scrcysb2m_as: 2020 Creatinine-Cystatin C-B2M Inker AJKD 2021
egfr3m_scrcysbtp_as: 2020 Creatinine-Cystatin C-BTP Inker AJKD 2021
egfr3m_cysb2mbtp_as: 2020 Cystatin C-B2M-BTP Inker AJKD 2021
egfr4m_as: 2020 Creatinine-Cystatin C-B2M-BTP Inker AJKD 2021
eGFRU25: U25 equations (SCr, Cys and average)
 Note that if any input marker is not available, the eGFR based on the
respective marker(s) would not be calculated

*/

%macro egfr_calc_ckdepi(data_in, age,female,black,height,
cr,cys,b2m,btp, name_out);

data &name_out.; set &data_in;

if &cr<=0.7 & &female=1 then do;
cf_cr=-0.329; cf_cc1=-0.248; cf_4m1=-0.24296; cf_ccb2m1=-0.192734414;
cf_ccbtp1=-0.242368992; cf_cr21=-0.241; cf_cc211=-0.219; end;
else if &cr<=0.9 & &female=0 then do;
```

```
cf_cr=-0.411; cf_cc1=-0.207; cf_4m1=-0.29481; cf_ccb2m1=-0.233821173;
cf_ccbtp1=-0.306793318; cf_cr21=-0.302; cf_cc211=-0.144; end;
else do;
cf_cr=-1.209; cf_cc1=-0.601; cf_4m1=-0.47131; cf_ccb2m1=-0.507357215;
cf_ccbtp1=-0.490505009; cf_cr21=-1.200; cf_cc211=-0.544; end;

if &cys<=0.8 then do;
cf_cy=-0.499; cf_cc2=-0.375; cf_3m1=-0.87628; cf_4m2=-0.51938;
cf_ccb2m2=-0.434860516; cf_ccbtp2=-0.594939205; cf_cc212=-0.323; end;
else do;
cf_cy=-1.328; cf_cc2=-0.711; cf_3m1=-0.69654; cf_4m2=-0.42276;
cf_ccb2m2=-0.508049507; cf_ccbtp2=-0.505001311; cf_cc212=-0.778; end;

if &btp<=0.6 then do;
cf_3m2=0.03763; cf_4m3=-0.00369; cf_ccbtp3=-0.005268947; end;
else do;
cf_3m2=-0.24332; cf_4m3=-0.17710; cf_ccbtp3=-0.199563102; end;


*2009 CKD-EPI Creatinine, Levey et al Annals 2009;
egfrcr= 141 *(1.018*&female + 1*(1-&female)) *(&cr/(0.7*&female +
0.9*(1-&female)))**cf_cr *0.993**&age *(1.159*&black + 1*(1-&black));

*2012 CKD-EPI Cystatin C Inker NEJM 2012;
egfrcys= 133 *(&cys/0.8)**cf_cy *0.996**age *(0.932*&female + 1*(1-
&female));

*2012 CKD-EPI Creatinine-Cystatin C Inker NEJM 2012;
egfrcc= 135 *(0.969*&female + 1*(1-&female)) *(&cr/(0.7*&female +
0.9*(1-&female)))**cf_cc1 *(&cys/0.8)**cf_cc2 *0.995**&age
*(1.08*&black + 1*(1-&black));

*2021 CKD-EPI Creatinine, Inker NEJM 2021;
egfr_cr21_as= 142 *(1.012*&female + 1*(1-&female)) *(&cr/(0.7*&female
+ 0.9*(1-&female)))**cf_cr21 *0.9938**&age;

*2021 CKD-EPI Creatinine-Cystatin C Inker NEJM 2021;
egfr_cc21_as= 135 *(0.963*&female + 1*(1-&female)) *(&cr/(0.7*&female
+ 0.9*(1-&female)))**cf_cc211 *(&cys/0.8)**cf_cc212 *0.9961**&age;



*2020 Cys-B2M-BTP 3-marker AS, Inker et al AJKD 2021;
egfr3m_cysb2mbtp_as=exp( 4.78473 -0.08106*&female -0.00136*&age
+cf_3m1*(log(&cys)-log(0.8)) +cf_3m2*(log(&btp)-log(0.6)) -
0.20539*log(&b2m) );
*2020 Cr-cys-B2M-BTP 4-marker AS, Inker et al AJKD 2021);
egfr4m_as=exp( 4.87408 -0.06546*&female -0.00370*&age
+cf_4m1*(log(&cr)-log(0.7*&female + 0.9*(1-&female)))
+cf_4m2*(log(&cys)-log(0.8)) +cf_4m3*(log(&btp)-log(0.6)) -
0.10324*log(&b2m) );
```

```
*2020 Cr-cys-B2M 3-marker AS, Inker et al AJKD 2021;
egfr3m_scrcysb2m_as=exp( 4.913849588 -0.057542983*&female -
0.003658991*&age +cf_ccb2m1*(log(&cr)-log(0.7*&female + 0.9*(1-
&female))) +cf_ccb2m2*(log(&cys)-log(0.8)) -0.165382497*log(&b2m) );
*2020 Cr-cys-BTP 3-marker AS, Inker et al AJKD 2021;
egfr3m_scrcysbtp_as=exp( 4.836942024 -0.068906753*&female -
0.00397527*&age +cf_ccbtp1*(log(&cr)-log(0.7*&female + 0.9*(1-
&female))) +cf_ccbtp2*(log(&cys)-log(0.8)) +cf_ccbtp3*(log(&btp)-
log(0.6)) );

*U25;
if &female=0 and &age < 12 then do;
      ckidKscr = 39.0 * (1.008**(&age-12));
      ckidKcys = 87.2 * (1.011**(&age-15));
end;
if &female=0 and &age >= 12 and &age <15 then do;
      ckidKscr = 39.0 * (1.045**(&age-12));
      ckidKcys = 87.2 * (1.011**(&age-15));
end;
if &female=0 and &age >= 15 and &age <18 then do;
      ckidKscr = 39.0 * (1.045**(&age-12));
      ckidKcys = 87.2 * (0.960**(&age-15));
end;
if &female=0 and &age >= 18 then do;
      ckidKscr = 50.8;
      ckidKcys = 77.1;
end;
*female;
if &female=1 and &age < 12 then do;
      ckidKscr = 36.1 * (1.008**(&age-12));
      ckidKcys = 79.9 * (1.004**(&age-12));
end;
if &female=1 and &age >= 12 and &age <18 then do;
      ckidKscr = 36.1 * (1.023**(&age-12));
      ckidKcys = 79.9 * (0.974**(&age-12));
end;
if &female=1 and &age >= 18 then do;
      ckidKscr = 41.4;
      ckidKcys = 68.3;
end;

eGFRU25scr= ckidKscr * &height / &cr ;
eGFRU25cys= ckidKcys * (1 / &cys) ;
eGFRU25ave= (eGFRU25scr + eGFRU25cys)/2;

egfr_tplnt=exp( 4.42755 -0.82305*log(&cr) -0.01243*&cr*&cr -
0.00551*&age +0.18065*(1-&female) );

run;

data &name_out.; set &name_out.;
     drop cf_cr cf_cy cf_cc1 cf_cc2 cf_3m1 cf_3m2
```

```
          cf_4m1 cf_4m2 cf_4m3 cf_cr21 cf_cc211 cf_cc212
             ckidKscr ckidKcys;
run;

%mend;
```