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### R code for eGFR calculation

```
####Function egfr.calc
##### Version 29 Sept 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
# 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
# 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
# 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, scr=NULL, cys=NULL, b2m=NULL, btp=NULL, digits=0,
merge=T, export=NULL){
```

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```
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_srcysb2m_as=NULL; egfr3m_srcysbtp_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)))
    +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)) )
}

```

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```
#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) )
}

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_srcrcysb2m_as,egfr3m_srcrcysbtp_as,egfr3m_cysb2mbtp_as,egfr4m_as))
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$cid_demo,d.demo$age,d.demo$female,d.demo$black,
  scr=d.demo$creatinine,cys=d.demo$scystatinc,b2m=d.demo$b2m,btp=d.demo$btp,
  export="G:/data_out.csv")
```

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### 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
  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
  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, 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;
```

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```
egfr3m_srccysb2m_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_srccysbtp_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)) );
```

```
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; run;
```

```
%mend;
```