

# Package ‘DVHmetrics’

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**Title** Analyze Dose-Volume Histograms and Check Constraints

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**Description** Functionality for analyzing dose-volume histograms (DVH) in radiation oncology: Read DVH text files, calculate DVH metrics as well as generalized equivalent uniform dose (gEUD), biologically effective dose (BED), equivalent dose in 2 Gy fractions (EQD2), normal tissue complication probability (NTCP), and tumor control probability (TCP). Show DVH diagrams, check and visualize quality assurance constraints for the DVH. Includes web-based graphical user interface.

**License** GPL (>= 2)

**URL** <https://github.com/dwoll/DVHmetrics/>

**NeedsCompilation** no

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DVHmetrics-package      *Analyze Dose-Volume Histograms and Check Constraints*

---

## Description

Functionality for analyzing dose-volume histograms (DVH) in radiation oncology: Read DVH text files, calculate DVH metrics, gEUD, BED, EQD2, NTCP, TCP, show DVH diagrams, check and visualize quality assurance constraints for the DVH. Includes web-based graphical user interface.

## Details

Package: DVHmetrics  
 Type: Package  
 Version: 0.4.2  
 Date: 2022-03-23  
 License: GPL (>= 2)

**Author(s)**

Daniel Wollschlaeger and Heiko Karle

Maintainer: Daniel Wollschlaeger <wollschlaeger@uni-mainz.de>

**References**

For a solution that also reads files in DICOM-RT format, see the RadOnc package: <https://CRAN.R-project.org/package=RadOnc>.

**Examples**

```
showDVH(dataMZ[[1]])
checkConstraint(dataMZ, "D1CC < 10Gy")
```

---

checkConstraint	<i>Check constraints on dose-volume histograms (DVH)</i>
-----------------	--

---

**Description**

Simultaneously checks one or more quality assurance constraints on one or more DVHs. Reports compliance with each constraint as well as observed difference between linearly interpolated DVH and the given constraints in terms of (relative) dose, (relative) volume, and (relative) minimal Euclidean distance.

**Usage**

```
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
               sortBy=c("none", "observed", "compliance", "structure",
                        "constraint", "patID", "deltaV", "deltaD",
                        "dstMin", "dstMinRel"),
               interp=c("linear", "spline", "smooth"), ...)
```

```
## S3 method for class 'DVHs'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
               sortBy=c("none", "observed", "compliance", "structure",
                        "constraint", "patID", "deltaV", "deltaD",
                        "dstMin", "dstMinRel"),
               interp=c("linear", "spline", "smooth"), ...)
```

```
## S3 method for class 'DVHlst'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
               sortBy=c("none", "observed", "compliance", "structure",
```

```

        "constraint", "patID", "deltaV", "deltaD",
        "dstMin", "dstMinRel"),
    interp=c("linear", "spline", "smooth"), ...)

## S3 method for class 'DVHLstLst'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
               sortBy=c("none", "observed", "compliance", "structure",
                        "constraint", "patID", "deltaV", "deltaD",
                        "dstMin", "dstMinRel"),
               interp=c("linear", "spline", "smooth"), ...)

```

## Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
constr	One or more constraints - given as a character vector or as a data.frame. See <a href="#">Details</a> .
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLst: byPat=TRUE means that the DVHs are for one patient with multiple structures. byPat=FALSE means that the DVHs are for one structure from multiple patients. If x has class DVHLstLst: byPat=TRUE means that the DVHs are for multiple patients (list components of x) with multiple structures. byPat=FALSE means that the DVHs are for multiple structures (list components of x) from multiple patients.
semSign	logical. Meaning of the sign of the observed dose/volume differences between DVHs and constraints. semSign=TRUE means that negative differences indicate constraint compliance, positive differences indicate constraint violations. With semSign=FALSE, the algebraic differences are returned as is.
sortBy	character vector. Sorting criteria for the output data frame.
interp	character. Method of interpolation between DVH points: Linear interpolation using <a href="#">approx</a> , monotone Hermite spline interpolation using <a href="#">spline</a> , or local polynomial regression using <a href="#">locpoly</a> with kernel bandwidth chosen by the direct plug-in method using <a href="#">dpill</a> .
...	Additional parameters passed to <a href="#">getMetric</a> . Use for constraints on EUD (see <a href="#">getEUD</a> for parameter names), TCP (see <a href="#">getTCP</a> ), and NTCP (see <a href="#">getNTCP</a> ).

## Details

A DVH constraint is a character string that consists of three parts: The DVH metric, the comparison operator (<, >, <=, >=), and the reference value together with the measurement unit. See [getMetric](#) for defining a DVH metric, as well as for possible measurement units for dose and volume. For constraints involving the relative dose, the DVH must contain the prescription dose.

Some example constraints are "V10Gy > 80%" (more than 80% of the structure should have received 10Gy), "V20% < 10CC" (less than 10cm<sup>3</sup> of the structure should have received 20% of the prescription dose), or "D10CC > 500cGy" (The "hottest" 10cm<sup>3</sup> of the structure should have received more than 500cGy).

For constraints on DEUD, DNTCP and DTCP (see [getMetric](#)), the reference measurement unit must be Gy, cGy, even though NTCP and TCP are probabilities. Example: "DNTCP < 0.5Gy".

A DVH constraint can apply to a specific patient or to all patients, and to a specific structure or to all structures.

- If constraints apply to all patients/structures in `x`, `constr` can be a character vector with elements like the examples above.
- If constraints apply only to some patients/structures, `constr` must be a data frame with variables `constraint`, `patID` and `structure`. Each row then defines one constraint and its scope: `constraint` must be a character string with one constraint definition as in the examples above. `patID` must be either a character string with a valid patient ID or "\*" if the constraint applies to all patients. `structure` must be either a character string with a valid structure or "\*" if the constraint applies to all structures. If variable `patID` is missing from the data frame, the constraints apply to all available patients. If variable `structure` is missing from the data frame, the constraints apply to all available structures. See [readConstraint](#) for reading appropriate constraint data frames from external text files.

For calculating the minimal Euclidean distance between the constraint point and the DVH, the constraint point is orthogonally projected onto each DVH segment between (interpolated) DVH nodes. The relative Euclidean distance is the minimum of these distances divided by the distance of the constraint point to the closer one of both axes (dose and volume).

If volume or dose values outside the range of possible values for a structure are requested, metrics cannot be calculated, and the result will be NA with a warning.

## Value

A data frame with details on constraint compliance / violation.

<code>patID</code>	Patient ID
<code>structure</code>	Structure
<code>constraint</code>	The checked constraint
<code>observed</code>	The observed value for the metric given in the constraint
<code>compliance</code>	Does the DVH satisfy the constraint?
<code>deltaV</code>	Volume difference between constraint and observed DVH (for the constraint dose) in measurement unit specified by constraint
<code>deltaVpc</code>	Percent volume difference between constraint and observed DVH (for the constraint dose) relative to constraint volume
<code>deltaD</code>	Dose difference between constraint and observed DVH (for the constraint volume) in measurement unit specified by constraint
<code>deltaDpc</code>	Percent dose difference between constraint and observed DVH (for the constraint volume) relative to constraint dose
<code>dstMin</code>	Minimal Euclidean distance between constraint and the cumulative DVH, using linear interpolation
<code>ptMinD</code>	Dose coordinate of closest point on cumulative DVH to constraint
<code>ptMinV</code>	Volume coordinate of closest point on cumulative DVH to constraint

**See Also**

[getMetric](#), [getEUD](#), [getNTCP](#), [getTCP](#), [readConstraint](#), [saveConstraint](#), [showConstraint](#)

**Examples**

```
res <- checkConstraint(dataMZ, c("D10CC < 10Gy", "V20Gy < 20%"))
head(res)

# define constraints
constr <- data.frame(
  patID=c("P123", "P234"),
  structure=c("HEART", "*"),
  constraint=c("D1CC < 20Gy", "V10% > 8CC"),
  stringsAsFactors=FALSE) # this is important
checkConstraint(dataMZ, constr=constr)
```

---

 convertDVH

---

*Convert between differential and cumulative DVH*


---

**Description**

Convert between differential and cumulative DVH as well as between dose units.

**Usage**

```
convertDVH(x, toType=c("asis", "cumulative", "differential"),
  toDoseUnit=c("asis", "GY", "CGY"),
  interp=c("asis", "linear"),
  nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'matrix'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
  toDoseUnit=c("asis", "GY", "CGY"),
  interp=c("asis", "linear"),
  nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHs'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
  toDoseUnit=c("asis", "GY", "CGY"),
  interp=c("asis", "linear"),
  nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHlst'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
  toDoseUnit=c("asis", "GY", "CGY"),
  interp=c("asis", "linear"),
  nodes=NULL, rangeD=NULL, perDose=TRUE)
```

```
## S3 method for class 'DVHLstLst'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
           interp=c("asis", "linear"),
           nodes=NULL, rangeD=NULL, perDose=TRUE)
```

### Arguments

x	One DVH (object of class <code>matrix</code> or <code>DVHs</code> , multiple cumulative DVHs from one patient with multiple structures (object of class <code>DVHLst</code> ), or multiple cumulative DVHs from many patients, each with multiple structures (object of class <code>DVHLstLst</code> ). See <a href="#">readDVH</a> .
toType	character. Convert the DVH to this type. "asis" keeps the current DVH type.
toDoseUnit	character. Convert the DVH to this dose unit. "asis" keeps the current dose unit.
interp	character. Interpolation method for the cumulative DVH. "asis" for no interpolation and "linear" for linear interpolation.
nodes	numeric. Minimum number of nodes to use in linear interpolation. Number of available nodes is kept as is for NULL or if larger than nodes.
rangeD	numeric. Dose range for linear interpolation method. If NULL it is determined individually for each DVH.
perDose	logical. Are the differential DVH volume values per unit dose?

### Value

Depending on the input, an object of class `matrix`, `DVHs`, `DVHLst`, or `DVHLstLst`.

### See Also

[convertDVHsmooth](#), [readDVH](#), [showDVH](#)

### Examples

```
res <- convertDVH(dataMZ[[c(1, 1)]],
                 toType="cumulative",
                 toDoseUnit="CGY")
```

---

convertDVHsmooth

*Convert between differential and cumulative DVH*

---

### Description

Convert between differential and cumulative DVH as well as between dose units, using smoothing of the differential DVH.

**Usage**

```

convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'matrix'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHs'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLst'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLstLst'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

```

**Arguments**

x	One DVH (object of class <code>matrix</code> or <code>DVHs</code> , multiple cumulative DVHs from one patient with multiple structures (object of class <code>DVHLst</code> ), or multiple cumulative DVHs from many patients, each with multiple structures (object of class <code>DVHLstLst</code> ). See <a href="#">readDVH</a> .
toType	character. Convert the DVH to this type. "asis" keeps the current DVH type.
toDoseUnit	character. Convert the DVH to this dose unit. "asis" keeps the current dose unit.
interp	character. Interpolation method for the differential DVH. "asis" and "linear" for no interpolation. "spline" for spline interpolation using <a href="#">splinefun</a> ("fmm" for differential, "monoH.FC" for cumulative DVHs), "ksmooth" for local polynomial regression using <a href="#">locpoly</a> with kernel bandwidth chosen by the direct

	plug-in method using <code>dpill</code> , "smoothSpl" for a smoothing spline using <code>smooth.spline</code> , with the smoothing parameter chosen by generalized crossvalidation.
nodes	numeric. Minimum number of nodes to use in interpolation for method "ksmooth". Number of available nodes is kept as is for NULL or if larger than nodes.
ranged	numeric. Dose range for interpolation methods "linear", "spline", "smoothSpl". If NULL it is determined individually for each DVH.
perDose	logical. Are the differential DVH volume values per unit dose?

**Value**

Depending on the input, an object of class `matrix`, `DVHs`, `DVHLst`, or `DVHLstLst`.

**See Also**

[convertDVH](#), [readDVH](#), [showDVH](#)

**Examples**

```
res <- convertDVHsmooth(dataMZ[[c(1, 1)]],
                        toType="cumulative",
                        toDoseUnit="CGY")
```

---

dataConstr	<i>Constraint data frame</i>
------------	------------------------------

---

**Description**

Data frame with quality assurance constraints to use with built-in DVH object `dataMZ`.

**Usage**

```
data(dataConstr)
```

**Format**

A data frame with 6 entries for the following 3 variables.

`constraint` The constraint character string.

`patID` The patient ID character string or \* wildcard.

`structure` The structure character string or \* wildcard.

**Details**

See [checkConstraint](#) for the definition of a constraint.

**See Also**

[readConstraint](#), [checkConstraint](#), [showConstraint](#)

**Examples**

```
checkConstraint(dataMZ, constr=dataConstr)
```

---

dataMZ	<i>DVH data from 3 patients</i>
--------	---------------------------------

---

**Description**

Data from 3 patients with radiotherapy. DVHs for 7 heart structures.

**Usage**

```
data(dataMZ)
```

**Format**

Object of class DVHLstLst with 3 components corresponding to 3 patients.

P123 Object of class DVHLst. 7 objects of class DVHs for structures AMYOCL (left anterior heart wall), AMYOCL (right anterior heart wall), AOVALVE (aortic valve), AVNODE (AV node), HEART (complete heart), PULMVALVE (pulmonary valve), MYOCARD (heart wall)

P234 Object of class DVHLst. 7 objects of class DVHs for the same structures as patient P123.

P345 Object of class DVHLst. 7 objects of class DVHs for the same structures as patient P123.

**Details**

Data courtesy of Department of Radiation Oncology (Prof. Dr. Schmidberger), University Medical Center Mainz, Germany.

See [readDVH](#) for classes DVHLstLst, DVHLst, and DVHs.

**See Also**

[readDVH](#), [print.DVHs](#)

**Examples**

```
print(dataMZ, verbose=TRUE)
```

---

getBED                      *Calculate biologically effective dose (BED)*

---

### Description

Calculate biologically effective dose (BED) according to the linear-quadratic model.

### Usage

```
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## Default S3 method:
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHs'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLst'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLstLst'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

### Arguments

D	Default: Total dose. If NULL, fn must be given. Alternative: One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
fd	Fractional dose. If D is some kind of DVH object, only the first element will be used.
fn	Number of fractions. If NULL, D must be the total dose. Ignored if D is some kind of DVH object.
ab	alpha/beta ratio for the relevant tissue. If some kind of DVH object, only the first element will be used.

### Value

Default method: A data frame with variables BED, fractDose, ab.

If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to BED.

### References

Fowler, J. F. (2010). 21 years of Biologically Effective Dose. *British Journal of Radiology*, 83, 554-568.

**See Also**

[getEQD2](#), [getIsoEffD](#)

**Examples**

```
getBED(D=50, fd=2.5, ab=c(2, 3, 4))
getBED(D=dataMZ[[c(1, 1)]], fd=1.8, ab=3)
```

---

getDMEAN

*DMEAN and other dose metrics*

---

**Description**

Calculate DMEAN and other dose metrics from the (interpolated) differential DVH without relying on the values exported by the TPS.

**Usage**

```
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHs'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHLst'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHLstLst'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)
```

**Arguments**

x	One DVH (object of class DVHs, multiple DVHs from one patient with multiple structures (object of class DVHLst), or multiple DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
interp	character. Method of interpolation between DVH points: Linear interpolation applies to the cumulative DVH (recommended). Spline interpolation with <a href="#">splinefun</a> , local polynomial regression with <a href="#">locpoly</a> , and smoothing splines with <a href="#">smooth.spline</a> apply to the differential DVH (not recommended).
nodes	numeric. Minimum number of nodes to use in interpolation. Number of available nodes is kept as is for NULL or if larger than nodes.

**Value**

A data frame with the following value(s).

**patID** Patient ID.

**structure** Structure name.

**doseMin** Minimum dose.

**doseMax** Maximum dose.

**doseAvg** Mean dose.

**doseMed** Median dose.

**doseSD** Dose standard deviation.

**doseMode** Dose mode.

**doseAvgTPS** Mean dose as exported from the TPS (if available).

**doseMedTPS** Median dose as exported from the TPS (if available).

**doseMinTPS** Minimum dose as exported from the TPS (if available).

**doseMaxTPS** Maximum dose as exported from the TPS (if available).

**See Also**

[getMetric](#), [convertDVHsmooth](#), [approxfun](#), [splinefun](#), [smooth.spline](#), [dpill](#), [locpoly](#)

**Examples**

```
getDMEAN(dataMZ[[1]], interp="linear")
```

---

```
getEQD2
```

*2Gy fractions biologically equivalent dose (EQD2)*

---

**Description**

Calculate dose in 2Gy fractions biologically equivalent dose according to the linear-quadratic model, assuming a homogeneous dose distribution within the volume.

**Usage**

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

```
## Default S3 method:
```

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

```
## S3 method for class 'DVHs'
```

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

```
## S3 method for class 'DVHlst'
```

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

```
## S3 method for class 'DVHlstLst'
```

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

## Arguments

D	Default: Total dose. If NULL, fn must be given. Alternative: One cumulative DVH (object of class DVHs), multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
fd	Fractional dose. If D is some kind of DVH object, only the first element will be used.
fn	Number of fractions. If NULL, D must be given. Ignored if D is some kind of DVH object.
ab	alpha/beta ratio for the relevant tissue. If D is some kind of DVH object, only the first element will be used.

## Details

EQD2 is a special case of isoeffective dose calculation with fractional dose  $d_2=2$ , see [getIsoEffD](#). The calculation assumes a homogeneous dose distribution within the volume.

## Value

Default method: A data frame with variables EQD2, fractDose, ab.

If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to EQD2.

## References

IAEA, & ICRU. (2008). Relative biological effectiveness in ion-beam therapy (Tech. Rep. No. IAEA-TR 461). Vienna, Austria: IAEA (International Atomic Energy Agency) and ICRU (International Commission on Radiation Units and Measurements).

## See Also

[getBED](#), [getIsoEffD](#)

## Examples

```
getEQD2(D=50, fd=2.5, ab=c(2, 3, 4))
getEQD2(dataMZ[[c(1, 1)]], fd=1.8, ab=3)
```

---

getEUD *Generalized equivalent uniform dose (gEUD)*

---

### Description

Calculate generalized equivalent uniform dose (gEUD). May be based on EQD2.

### Usage

```
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHs'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHLst'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHLstLst'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)
```

### Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
EUDa	Exponential parameter a.
EUDfd	If gEUD should be based on EQD2: Fraction dose.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
...	Ignored. Used to catch additional arguments passed from <a href="#">getMetric</a> .

### Value

A data frame with variables EUD, patID, and structure.

### References

Niemierko, A. (1999). A generalized concept of equivalent uniform dose. *Medical Physics*, 26(6), 1100.

Wu et al. (2002). Optimization of intensity modulated radiotherapy plans based on the equivalent uniform dose. *International Journal of Radiation Oncology Biology Physics*, 52, 224-235.

### See Also

[getEQD2](#), [getMetric](#)

**Examples**

```
getEUD(dataMZ[[1]], EUDa=2)

# based on EQD2
getEUD(dataMZ[[1]], EUDa=2, EUDfd=1.8, EUDab=4)
```

---

getIsoEffD

*Isoeffective dose calculation*


---

**Description**

Convert given (fractional) dose into a corresponding (fractional) dose for a different total dose / fractionation schedule according to the linear-quadratic model.

**Usage**

```
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## Default S3 method:
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHs'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHLst'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHLstLst'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)
```

**Arguments**

D1	Default: numeric vector. Total dose 1. Alternative: One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
D2	numeric vector. Total dose 2. Ignored if D is some kind of DVH object.
fd1	numeric vector. Fractional dose 1. If D is some kind of DVH object, only the first element will be used.
fd2	numeric vector. Fractional dose 2. If D is some kind of DVH object, only the first element will be used.
ab	numeric vector. alpha/beta ratio for the relevant tissue in the linear-quadratic model. If D is some kind of DVH object, only the first element will be used.

**Details**

DVH methods: Calculate D2 based on D1, fd1, fd2, and ab. The default method can also calculate fd2 based on D1, D2, fd1, and ab.

**Value**

The (vector of) corresponding (fractional) dose value(s). If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to D2.

**References**

IAEA, & ICRU. (2008). Relative biological effectiveness in ion-beam therapy (Tech. Rep. No. IAEA-TR 461). Vienna, Austria: IAEA (International Atomic Energy Agency) and ICRU (International Commission on Radiation Units and Measurements).

**See Also**

[getBED](#), [getEQD2](#)

**Examples**

```
# reference: 70Gy in 2Gy fractions
# new fractionation: 3Gy fractions
# calculate corresponding dose
(D2 <- getIsoEffD(D1=70, fd1=2, fd2=3, ab=c(3.5, 10)))

getIsoEffD(D1=dataMZ[[c(1, 1)]], fd1=1.8, fd2=2, ab=3.5)
```

---

getMeanDVH

*Point-wise mean DVH with point-wise SDs*

---

**Description**

Returns the point-wise mean and median DVH with the point-wise standard deviation for a given list of input DVHs. Other point-wise measures may be calculated as well.

**Usage**

```
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE, returnDVHobj=FALSE)

## S3 method for class 'DVHs'
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE, returnDVHobj=FALSE)

## S3 method for class 'DVHlst'
```

```

getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
            cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
            fixed=TRUE, returnDVHObj=FALSE)

## S3 method for class 'DVHLstLst'
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
            cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
            fixed=TRUE, returnDVHObj=FALSE)

```

### Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
fun	Named list of functions that should be applied to yield 1 point-wise DVH measure. Functions must have exactly 1 return value.
cumul	logical. Get point-wise mean and SD for cumulative or differential (per unit dose) DVH?
thin	numeric. The number of DVH nodes (dose values) is reduced by 1/thin of the maximum number of nodes in x before interpolating and averaging.
byPat	logical. Relevant if multiple DVHs are given. byPat=TRUE means that for each patient, DVHs for multiple structures are averaged point wise. byPat=FALSE means that for each structure, DVHs for multiple patients averaged point wise.
patID	character vector. Include DVHs for these patients only when calculating mean/SD. If missing, all patients are used. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
structure	character vector. Include DVHs for these structures only when calculating mean/SD. If missing, all structures are used. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.
returnDVHObj	logical. With returnDVHObj=TRUE, a regular DVH object is returned. In that case, fun may only have one component for calculating either the point-wise mean or median.

### Details

Before calculating the point-wise mean and SD, DVHs in x are first linearly interpolated with [convertDVH](#) using the same set of nodes.

### Value

By default (returnDVHObj=FALSE) returns a data frame with point-wise mean DVH averaged over structures (byPat=TRUE) or over patients (byPat=FALSE) including the point-wise standard deviation or other measures as controlled by fun. With returnDVHObj=TRUE, a DVH object is returned that is equivalent to a DVH as imported from a file. In particular, functions like [showDVH](#) or [getMetric](#) can be used on such an object.

**See Also**

[showDVH](#), [convertDVH](#)

**Examples**

```
res1 <- getMeanDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))
head(res1)

# average differential DVHs
# matches patients P123 and P234
res2 <- getMeanDVH(dataMZ, fun=list(min=min, max=max),
                  cumul=FALSE, byPat=FALSE,
                  patID="23", fixed=FALSE)

head(res2)
```

---

getMetric

*Calculate dose-volume-histogram metrics*


---

**Description**

Simultaneously calculates multiple metrics for multiple cumulative DVHs.

**Usage**

```
getMetric(x, metric, patID, structure,
         sortBy=c("none", "observed", "patID", "structure", "metric"),
         splitBy=c("none", "patID", "structure", "metric"),
         interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHs'
getMetric(x, metric, patID, structure,
         sortBy=c("none", "observed", "patID", "structure", "metric"),
         splitBy=c("none", "patID", "structure", "metric"),
         interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHLst'
getMetric(x, metric, patID, structure,
         sortBy=c("none", "observed", "patID", "structure", "metric"),
         splitBy=c("none", "patID", "structure", "metric"),
         interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHLstLst'
getMetric(x, metric, patID, structure,
         sortBy=c("none", "observed", "patID", "structure", "metric"),
         splitBy=c("none", "patID", "structure", "metric"),
         interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)
```

**Arguments**

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHlst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHlstLst). See <a href="#">readDVH</a> .
metric	character vector defining one or more DVH metrics. See Details for their definition. For metrics involving the relative dose, the DVH must contain the prescription dose.
patID	character vector. Calculate given DVH metrics for these patients only. If missing, DVH metrics are calculated for all patients. Can be a regular expression if additional argument <code>fixed=FALSE</code> is supplied as well, see <a href="#">regex</a> .
structure	character vector. Calculate given DVH metrics for these structures only. If missing, DVH metrics are calculated for all structures. Can be a regular expression if additional argument <code>fixed=FALSE</code> is supplied as well, see <a href="#">regex</a> .
sortBy	character vector giving the sorting criteria for the output data frame.
splitBy	character vector. Split results into a list of data frames where list components are defined by groups from combining these variables.
interp	character. Method of interpolation between DVH points: Linear interpolation using <a href="#">approx</a> , monotone Hermite spline interpolation using <a href="#">splinefun</a> , or local polynomial regression using <a href="#">locpoly</a> with kernel bandwidth chosen by the direct plug-in method using <a href="#">dpill</a> .
fixed	logical. Use <code>fixed=FALSE</code> for regular expression matching of <code>patID</code> and <code>structure</code> .
...	Further arguments passed to <a href="#">getEUD</a> (for <code>metric="DEUD"</code> ), <a href="#">getTCP</a> (for <code>metric="DTCP"</code> ), or <a href="#">getNTCP</a> (for <code>metric="DNTCP"</code> ).

**Details**

A *pre-specified* DVH metric is one of the following character strings:

- "DMEAN": The volume-weighted mean dose of the structure.
- "DMEDIAN": Median dose, equal to D50%
- "DMIN": The minimum dose of the non-zero-dose voxels in the structure.
- "DMAX": The maximum dose of the non-zero-dose voxels in the structure.
- "DSD": The standard deviation of the dose in the structure.
- "DRX": The prescription dose.
- "DHI": The Homogeneity Index according to ICRU 83:  $(D2\% - D98\%) / D50\%$ .
- "DEUD": The generalized equivalent uniform dose (gEUD). See [getEUD](#) for mandatory and optional parameters.
- "DNTCP": The normal tissue complication probability (NTCP). See [getNTCP](#) for mandatory and optional parameters.
- "DTCP": The tumor control probability (TCP). See [getNTCP](#) for mandatory and optional parameters.

A *free* DVH metric is a character string which has three mandatory elements and one optional element in the following order (AAPM TG263 2018, section 9.2, note that complementary / cold metrics are not yet implemented):

- 1st letter "D" or "V": "D" If the requested value is a dose, "V" if it is a volume.
- 2nd element <number>: If the first letter is "D", this gives the volume for which the dose value of the cumulative DVH should be reported. If the first letter is "V", this gives the dose for which the volume value of the cumulative DVH should be reported.
- 3rd element <measurement unit>: The measurement unit for the 2nd element of the metric. Absolute volumes are indicated by "CC" for cubic centimeter, relative volumes by "%". Absolute doses are indicated by "Gy" for Gray, "cGy" for Centigray, or "eV/g" for uncalibrated dose in DVHs exported by PRIMO. Relative doses are indicated by "%".
- Optional 4th element <measurement unit>: The measurement unit of the output value. Possible units are as for the 3rd element. If missing, dose is reported as absolute dose in the measurement unit used in the DVH. Volume is reported as relative volume in %.

Examples:

- "D1%": Minimal absolute dose for the "hottest" 1% of the structure, i.e., the maximally irradiated 1% of the structure was exposed to at least this absolute dose.
- "D1CC\_%": Minimal relative dose (% of prescription dose) for the maximally irradiated cm<sup>3</sup> of the structure.
- "V500cGy": Relative structure volume in % that was exposed to at least 500cGy.
- "V10%\_CC": Absolute structure volume in cm<sup>3</sup> that was exposed to at least 10% of prescription dose.

If volume or dose values outside the range of possible values for a structure are requested, metrics cannot be calculated, and the result will be NA with a warning.

DMEAN, DMEDIAN, DMIN, DMAX, DSD are taken from the exported DVH if present. Otherwise, the differential DVH is generated and used for calculating these metrics.

## Value

A data frame or a list with details on the calculated metrics.

patID	Patient ID
structure	Structure
metric	The calculated DVH metric
observed	The observed value for the DVH metric

## References

American Association of Physicists in Medicine (AAPM) Task Group TG263 (2018). Standardizing Nomenclatures in Radiation Oncology. [https://www.aapm.org/pubs/reports/RPT\\_263.pdf](https://www.aapm.org/pubs/reports/RPT_263.pdf) (section 9.2 "Guidelines for DVH metrics")

Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). *Radiotherapy Oncology*, 73, 21-32.

Wu et al. (2002). Optimization of intensity modulated radiotherapy plans based on the equivalent uniform dose. *International Journal of Radiation Oncology Biology Physics*, 52, 224-235.

**See Also**

[saveMetric](#), [getEUD](#), [getNTCP](#), [getTCP](#), [getEQD2](#), [approxfun](#), [splinefun](#), [dpill](#), [locpoly](#)

**Examples**

```
getMetric(dataMZ, c("D1CC", "V10%_CC"),
          sortBy=c("metric", "structure", "observed"))

# matching patients are P123 and P234
# matching structures are AMYOCL and AMYOCL
getMetric(dataMZ, c("D1CC", "V10%_CC"),
          patID="23",
          structure=c("AMYOC", "VALVE"),
          splitBy="patID",
          fixed=FALSE)

# gEUD with a=2
getMetric(dataMZ[[c(1, 1)]], "DEUD", EUDa=2)

# gEUD based on EQD2 with a=2, 20 fractions
getMetric(dataMZ[[c(1, 1)]], "DEUD", EUDa=2, EUDfd=1.8)

# NTCP Lyman probit model with TD50=20, m=4, n=0.5
getMetric(dataMZ[[c(1, 1)]], "DNTCP",
          NTCPTd50=20, NTCpm=4, NTCpn=0.5, NTCptype="probit")
```

---

getNTCP

*Normal tissue complication probability (NTCP)*

---

**Description**

Calculate normal tissue complication probability (NTCP) from Lyman's probit model, Niemierko's logit model, the Poisson model, or the Kaellman relative seriality model. May be based on EQD2.

**Usage**

```
getNTCP(x,
        NTCPTd50=NULL, NTCpm=NULL, NTCpn=NULL, NTCPgamma50=NULL, NTCps=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCptype=c("probit", "logit", "poisson", "relative_seriality"), ...)

## S3 method for class 'DVHs'
getNTCP(x,
        NTCPTd50=NULL, NTCpm=NULL, NTCpn=NULL, NTCPgamma50=NULL, NTCps=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCptype=c("probit", "logit", "poisson", "relative_seriality"), ...)

## S3 method for class 'DVHlst'
```

```

getNTCP(x,
        NTCPTd50=NULL, NTCpm=NULL, NTCpn=NULL, NTCPgamma50=NULL, NTCps=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCptype=c("probit", "logit", "poisson", "relative_seriality"), ...)

## S3 method for class 'DVHLstLst'
getNTCP(x,
        NTCPTd50=NULL, NTCpm=NULL, NTCpn=NULL, NTCPgamma50=NULL, NTCps=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCptype=c("probit", "logit", "poisson", "relative_seriality"), ...)

```

### Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> ).
NTCPTd50	Tolerance dose with 50% complication probability.
NTCpm	Probit/logit Parameter m. Equal to $1 / (\text{NTCPgamma50} * \sqrt{2 * \pi})$ .
NTCpn	Parameter n. Equal to $1/a$ with exponential gEUD paramter a.
NTCPgamma50	Poisson parameter gamma50. Equal to $1 / (\text{NTCpm} * \sqrt{2 * \pi})$
NTCps	Relative seriality parameter s.
EUDa	If gEUD should be based on EQD2: Exponential parameter a.
EUDfn	If gEUD should be based on EQD2: Number of fractions.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
NTCptype	"probit" - Lyman probit model, "logit" - Niemierko logit model, "poisson" - Poisson model, "relative_seriality" - Kaellmann relative seriality model.
...	Ignored. Used to catch additional arguments passed from <a href="#">getMetric</a> .

### Details

For the logit, probit, and Poisson method, gEUD is used for DVH reduction. This is equivalent to the Kutcher-Burman DVH reduction scheme. The probit model is given in equation (1), the logit model in equation (2), and the Poisson model in equation (3) in Kaellman (1992), with gEUD plugged in for D. The relative seriality model is given in equation (18).

### Value

A data frame with variables NTCP, patID, and structure.

### References

- Kaellman, P., Agren, A., & Brahme, A. (1992). Tumor and normal tissue responses to fractionated non-uniform dose delivery. *International Journal of Radiation Biology*, 62(2), 249-262.
- Kutcher, G. J., Burman, C., Brewster L., Goitein, M., & Mohan, R. (1991). Histogram reduction method for calculating complication probabilities for threedimensional treatment planning evaluations. *International Journal of Radiation Oncology Biology Physics*, 21(1), 137-146.

Lyman, J. T. (1985). Complication probability as assessed from dose volume histograms. *Radiation Research*, 104(2), S13-19.

Niemierko, A. (1999). A generalized concept of equivalent uniform dose. *Medical Physics*, 26(6), 1100.

Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). *Radiotherapy Oncology*, 73, 21-32.

### See Also

[getTCP](#), [getEUD](#), [getMetric](#)

### Examples

```
## treatment was in 2 Gy fractions
getNTCP(dataMZ[[1]][["HEART"]],
        NTCPTd50=48, NTCpm=0.6, NTCpn=0.5, NTCpype="probit")

getNTCP(dataMZ[[1]][["HEART"]],
        NTCPTd50=52.3, NTCpgamma=1.28, NTCps=1, NTCpype="relative_seriality")
```

---

<code>getTCP</code>	<i>Tumor control probability (TCP)</i>
---------------------	--

---

### Description

Calculate tumor control probability (TCP) from Lyman's probit model, Niemierko's logit model, the Poisson model, or the Kaellman relative seriality model. May be based on EQD2.

### Usage

```
getTCP(x, TCPtcd50=NULL, TCPm=NULL, TCPn=NULL, TCPgamma50=NULL, NTCps=NULL,
      EUDa=NULL, EUDfn=NULL, EUDab=NULL,
      TCPtype=c("probit", "logit", "poisson", "relative_seriality"), ...)
```

### Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
TCPtcd50	Tolerance dose with 50% tumor control probability.
TCPm	Probit/logit Parameter m. Equal to $1 / (NTCPgamma50 * \sqrt{2 * \pi})$ .
TCPn	Parameter n. Equal to $1/a$ with exponential gEUD paramter a.
TCPgamma50	Poisson parameter gamma50. Equal to $1 / (NTCPm * \sqrt{2 * \pi})$
NTCps	Relative seriality parameter s.
EUDa	If gEUD should be based on EQD2: Exponential parameter a.

EUDfn	If gEUD should be based on EQD2: Number of fractions.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
TCptype	"probit" - Lyman probit model, "logit" - Niemierko logit model, "poisson" - Poisson model, "relative_seriality" - Kaellmann relative seriality model..
...	Ignored. Used to catch additional arguments passed from <a href="#">getMetric</a> .

## Details

For the logit, probit, and Poisson method, gEUD is used for DVH reduction. This is equivalent to the Kutcher-Burman DVH reduction scheme. The probit model is given in equation (1), the logit model in equation (2), and the Poisson model in equation (3) in Kaellman (1992), with gEUD plugged in for D. The relative seriality model is given in equation (18).

## Value

A data frame with variables TCP, patID, and structure.

## References

- Kaellman, P., Agren, A., & Brahme, A. (1992). Tumor and normal tissue responses to fractionated non-uniform dose delivery. *International Journal of Radiation Biology*, 62(2), 249-262.
- Kutcher, G. J., Burman, C., Brewster L., Goitein, M., & Mohan, R. (1991). Histogram reduction method for calculating complication probabilities for threedimensional treatment planning evaluations. *International Journal of Radiation Oncology Biology Physics*, 21(1), 137-146.
- Lyman, J. T. (1985). Complication probability as assessed from dose volume histograms. *Radiation Research*, 104(2), S13-19.
- Niemierko, A. (1999). A generalized concept of equivalent uniform dose. *Medical Physics*, 26(6), 1100.
- Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). *Radiotherapy Oncology*, 73, 21-32.

## See Also

[getNTCP](#), [getEUD](#), [getMetric](#)

## Examples

```
getTCP(dataMZ[[1]],
        TCPtcd50=40, TCPm=0.6, TCPn=0.5, TCptype="probit")
```

---

mergeDVH	<i>Merge existing DVH objects</i>
----------	-----------------------------------

---

### Description

Combine several existing DVH objects into one object.

### Usage

```
mergeDVH(...)
```

### Arguments

... DVHLstLst objects.

### Details

The first object determines whether the resulting object is organized by patient or by structure. Objects need not originally come from the same treatment planning system.

### Value

Returns an object of class DVHLstLst.

### Examples

```
## Not run:  
# pick some DVH files interactively  
a <- readDVH(type="Cadplan")  
  
# pick other DVH files interactively  
b <- readDVH(type="Eclipse")  
  
# combine DVH data  
res <- mergeDVH(a, b)  
res  
  
## End(Not run)
```

---

print.DVHs	<i>Print basic information about one or more DVHs</i>
------------	---

---

## Description

Print basic information (patients, structures, dose range) about one or more DVHs.

## Usage

```
## S3 method for class 'DVHs'  
print(x, ...)  
  
## S3 method for class 'DVHLst'  
print(x, ...)  
  
## S3 method for class 'DVHLstLst'  
print(x, ...)
```

## Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See <a href="#">readDVH</a> .
...	Further arguments: <code>print.DVHLst(x, verbose=TRUE)</code> prints more information about each DVH.

## Value

Prints summary information about the DVHs.

## See Also

[readDVH](#)

## Examples

```
print(dataMZ)  
print(dataMZ, verbose=TRUE)
```

---

readConstraint	<i>Read constraint definitions from text file</i>
----------------	---

---

### Description

Reads the definition of quality assurance constraints from a text file.

### Usage

```
readConstraint(x, ...)
```

### Arguments

x	character string giving the path to a single text file with the constraint definition. May contain globbing symbols understood by <a href="#">Sys.glob</a> . If missing and in interactive mode, readDVH opens a file selector widget. See Details.
...	Further arguments passed to <a href="#">read.table</a> , e.g., sep="\t" to define the column separator as tab.

### Details

This is a wrapper for [read.table](#).

The text file should contain three columns with the column names patID, structure, constraint in the first line. Each further line then defines one constraint and the scope it applies to in terms of patients and structures. See [checkConstraint](#) for the definition of a constraint and for the definition of a scope. Example content:

```
"patID" "structure" "constraint"  
"*" "HEART" "D1CC < 20Gy"  
"234" "*" "V10% > 8CC"
```

### Value

A data.frame with columns patID, structure, constraint that can be used in functions [checkConstraint](#) and [showConstraint](#).

### See Also

[read.table](#), [checkConstraint](#), [saveConstraint](#), [showConstraint](#)

### Examples

```
## Not run:  
readConstraint("constraint.txt")  
readConstraint()  
  
## End(Not run)
```

---

readDVH	<i>Read DVH text files</i>
---------	----------------------------

---

### Description

Reads single or multiple DVH text files as exported from Varian Eclipse(TM), CadPlan(TM), On-Centra MasterPlan(TM), Philipps Pinnacle3 (TM), Elekta Monaco (TM), Tomo HiArt (TM), Ray-Search Labs RayStation (TM), or Medcom ProSoma (TM). Supports cumulative and differential DVHs.

### Usage

```
readDVH(x,
        type=c("Eclipse", "Cadplan", "Masterplan",
              "Pinnacle", "Monaco", "HiArt",
              "RayStation", "ProSoma", "PRIMO"),
        planInfo=FALSE, courseAsID=FALSE, add, ...)
```

### Arguments

x	character vector giving paths to DVH text files. May contain globbing symbols understood by <a href="#">Sys.glob</a> . If missing and in interactive mode, readDVH opens a file selector widget. Under Windows, this widget allows selecting multiple files simultaneously. For type="Pinnacle", x should be one of the following: A directory with information for one patient, a directory with several sub-directories (one for each patient), or a zip file of such directories. Under Windows, if x is missing and type="Pinnacle", readDVH opens a folder selector widget.
type	character. Indicates which program the DVH text files were exported from. Supported: "Cadplan" (tested with version 6.4.7), "Eclipse" (tested with Varian Eclipse version 10-15), "Masterplan" (tested with OnCentra MasterPlan version 4.3), "Pinnacle" (tested with Pinnacle3 version 9, see Details), "Monaco" (tested with Elekta Monaco version 5), "HiArt" (TomoTherapy HiArt), "RayStation" (tested with RaySearch Labs RayStation version 9A), "ProSoma" (Medcom ProSoma), "PRIMO" (tested with version 0.3.1.1558).
planInfo	Experimental: Either FALSE or character string. In the latter case, readDVH tries to extract additional information from the Plan field in the DVH file, e.g., the prescription dose for a sum plan or the boost quadrant. Undocumented, see source.
courseAsID	logical. If TRUE, the Course entry in the header section of a DVH file is appended to the regular patient ID. Currently supported only for type="Eclipse".
add	DVHlst object. Existing object that should be merged with the new data from the files.
...	Additional arguments passed on to <a href="#">file</a> . Specify UTF-8 file encoding with encoding="UTF-8" or encoding="UTF-8-BOM" (when a byte-order-mark is used). Passing additional arguments is currently not supported when reading Pinnacle

files. Additional arguments are also used for type="HiArt" where a list `hiart` may be supplied that specifies patient IDs, absolute structure volumes, and prescription dose. Same for type="RayStation" with a list `raystation`. If Eclipse uncertainty plans are present, specify `uncertainty=TRUE` (see Details).

## Details

Absolute dose values need to be given in Gy, cGy, or eV/g for uncalibrated dose in DVHs exported by PRIMO. Absolute volume values need to be given in  $\text{cm}^3$ .

Differential DVHs are automatically converted to cumulative DVHs, but the differential DVH information is kept.

Sum plans are supported.

For Eclipse starting with version 13, the date format is locale dependent as it uses words for day and month. Importing those dates as class `Date` requires that the correct locale is set (see [Sys.setlocale](#)), and that files containing accents are read using the correct encoding (see above). Otherwise, date is stored as a character string.

For RayStation, only cumulative DVHs with absolute volume are currently supported. Volume is assumed to be measured in  $\text{cm}^3$ .

For files with absolute volume exported from Masterplan and Tomo HiArt, you can specify `volume_from_dvh=TRUE` if the structure volume should be guessed from the maximal volume given in the DVH for each structure.

Since files from HiArt, ProSoma and PRIMO do not contain info on patient ID, the current workaround is to generate a random ID.

To export data from Tomo HiArt, copy to clipboard and then save to file from a text editor. Support for Tomo HiArt files is currently limited to those with absolute dose. Please send an anonymized sample file if you need to read files with relative dose. You can provide a list `hiart` with more information about patients and structures. The list should have one component for each file you import. Each component itself has to be a named list with optional components

- `date` - a character string like "2022-01-16" for the date
- `patName` - a character string for patient name
- `patID` - a character string for patient ID
- `doseRx` - a character string like "50.4Gy" for prescription dose in the same dose unit as used in the DVHs
- `structVol` - a named character vector like `c("PTV"=750, "LUNG"=1250)` giving the absolute structure volumes with names equal to structure names
- `volumeUnit` - a character string, either "CC" or "cm3", for the structure volume unit)

The same approach can be used for RayStation files with a list `raystation`.

Pinnacle3 files have to be exported using its own scripting facility such that information from one patient is contained in one directory. A suitable export script is available on request from the package authors. The directory layout for one patient has to be as follows (experimental, likely to change in future versions):

- Files (CSV format with column headers):

- DoseInfo.csv (variables "PrescriptionDose cGy", "NumberOfFractions", "Dosis cGy")
- PatInfo.csv (variables "LastName", "FirstName", "MedicalRecordNumber")
- PlanInfo.csv (variable "PlanName")
- Directory: Data:
  - Info.csv (variables "Filename", "RegionOfInterestName", "DoseMin cGy", "DoseMax cGy", "DoseMean cGy", "Volume ccm")
  - DVH1.csv, DVH2.csv, ... - the actual DVH data files with names defined in Info.csv variable "Filename". They should look like
 

```
NumberOfDimensions = 2;
NumberOfPoints = 431;
Points[] ={
    0,0
    10,0
    ...
    4000,100
};
```

## Value

Returns an object of class DVHLstLst. This is a list (one component with class DVHLst for each original file from one patient) of lists (each component is an object of class DVHs). A DVHs object is a list with the following components:

dvh matrix - cumulative DVH values

dvhDiff matrix - differential DVH values, only created a) if original file contained a differential DVH or b) by [convertDVH](#)

patID character string - patient ID

date character string - date of DVH export

type character string - cumulative or differential DVH

plan character string - plan name

course character string - course - currently Eclipse only

structure character string - structure name

structVol numeric - structure volume

doseUnit character string - measurement unit dose

volumeUnit character string - measurement unit volume

doseRx numeric - prescription dose

isoDoseRx numeric - iso-dose percentage

doseMin numeric - minimum dose from DVH file

doseMax numeric - maximum dose from DVH file

doseAvg numeric - average dose from DVH file

doseMed numeric - median dose from DVH file

doseSD numeric - dose standard deviation from DVH file

**See Also**

[Sys.glob](#), [readLines](#), [print.DVHs](#), [showDVH](#), [getMetric](#), [checkConstraint](#), [convertDVH](#)

**Examples**

```
## Not run:
# pick DVH files interactively
res <- readDVH()
res

# read all txt files in subdirectory DVH
res <- readDVH("DVH/*.txt", type="Eclipse")
res

## End(Not run)
```

---

runGUI

*Open web-based GUI in browser*

---

**Description**

Opens the web-based GUI in an external browser.

**Usage**

```
runGUI(...)
```

**Arguments**

... Arguments passed to [runApp](#). Supply `port=80` if a web browser refuses to connect to the randomly chosen port for security reasons.

**Details**

This function calls [runApp](#) to run the included DVHshiny application. See `vignette("DVHshiny")` for documentation.

**See Also**

[runApp](#)

**Examples**

```
## Not run:
runGUI()

## End(Not run)
```

---

saveConstraint	<i>Save constraint result to file</i>
----------------	---------------------------------------

---

### Description

Saves results from [checkConstraint](#) to a text file.

### Usage

```
saveConstraint(x, ...)
```

### Arguments

x	data.frame - the result from <a href="#">checkConstraint</a> .
...	Further arguments passed to <a href="#">write.table</a> - e.g., file="<filename>" for the output filename, dec="." to define the decimal separator as point or sep="\t" to define the column separator as tab.

### Details

This is a wrapper for [write.table](#).

### See Also

[write.table](#), [checkConstraint](#)

### Examples

```
res <- checkConstraint(dataMZ, c("D10CC < 10Gy", "V20Gy < 20%"))
## Not run:
saveConstraint(res, file="constrResults.txt", sep="\t")

## End(Not run)
```

---

saveDVH	<i>Save DVH diagram to file</i>
---------	---------------------------------

---

### Description

Saves one or multiple DVH diagrams to file.

### Usage

```
saveDVH(x, file="", ...)
```

**Arguments**

x	A single <code>ggplot</code> object or a list of multiple <code>ggplot</code> objects as returned by <code>showDVH</code> or <code>showConstraint</code> .
file	character. Path to file. The file-ending determines what kind of file is written, e.g., "filename.pdf" will write a pdf document, "filename.jpg" a JPEG image.
...	Further arguments passed to <code>ggsave</code> , e.g., width and height to determine the figure size.

**Details**

This is a wrapper for `ggsave`.

**Value**

If x is a list of `ggplot` objects, one file is written for each list component. If x is a single `ggplot` object, one file is written.

**See Also**

`ggsave`, `showDVH`, `showConstraint`

**Examples**

```
res <- showDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))
## Not run:
saveDVH(res, "out.pdf")

## End(Not run)
```

---

saveMetric

*Save DVH metrics to file*

---

**Description**

Saves results from `getMetric` to a text file.

**Usage**

```
saveMetric(x, file = "", ...)
```

## S3 method for class 'data.frame'

```
saveMetric(x, file = "", ...)
```

## S3 method for class 'list'

```
saveMetric(x, file = "", ...)
```

**Arguments**

`x` data.frame or list - the result from `getMetric`.  
`file` character. Path to file.  
`...` Further arguments passed to `write.table` - e.g., `dec="."` to define the decimal separator as point or `sep="\t"` to define the column separator as tab.

**Details**

This is a wrapper for `write.table`.

**Value**

If `x` is a list, one text file is written for each list component. If `x` is a data.frame, one file is written.

**See Also**

`write.table`, `getMetric`

**Examples**

```
res <- getMetric(dataMZ, c("D1CC", "V10%_CC"),
                 sortBy=c("metric", "structure"),
                 splitBy="patID")

## Not run:
# not run
saveMetric(res, file="metricsResults.txt", sep="\t")

## End(Not run)
```

---

showConstraint

*Display constraints for cumulative dose-volume histograms*

---

**Description**

Displays quality assurance constraints for cumulative dose-volume histograms: Either one diagram per patient - including multiple structures. Or one diagram per structure - including multiple patients.

**Usage**

```
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
              thresh=1, show=TRUE, visible=FALSE)

## S3 method for class 'DVHs'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
              thresh=1, show=TRUE, visible=FALSE)
```

```
## S3 method for class 'DVHLst'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
              thresh=1, show=TRUE, visible=FALSE)

## S3 method for class 'DVHLstLst'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
              thresh=1, show=TRUE, visible=FALSE)
```

### Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See <a href="#">readDVH</a> . See Details.
constr	One or more constraints - given as a character vector or as a data.frame. See <a href="#">checkConstraint</a> for their definition.
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
rel	logical. Show relative volume?
guessX	logical. Try to guess the best x-axis limits for better visibility of main DVH range? If FALSE, x-axis runs from 0 to maximum dose. If TRUE, x-axis runs from 0 to dose value where volume approaches 0. If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
guessY	logical. Try to guess the best y-axis limits? If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+10%) such that the "highest" DVH is cut off at this relative volume.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only <a href="#">ggplot</a> diagram objects are silently returned.
visible	logical. Return <a href="#">ggplot</a> diagram object visibly or invisibly. show=FALSE with visible=TRUE is useful for zooming in shiny apps.

### Details

Constraints are shown as points in the cumulative DVH with an additional arrow indicating where the cumulative DVH curve should lie relative to the constraint. On each DVH curve, the point with the minimal Euclidean distance to the constraint is indicated. Note that, visually, this point only has the minimal apparent distance if the aspect ratio of the diagram is 1.

If multiple diagrams are produced, they are shown in the same graphics device. If interactive inspection is required, make sure you use an R development environment that saves previous diagrams and allows navigating between them - e.g., [RStudio](#) or [OpenAnalytics Architect](#).

**Value**

Silently returns a [ggplot](#) diagram object, or - when multiple diagrams are constructed - a list of [ggplot](#) diagram objects.

**See Also**

[checkConstraint](#), [saveDVH](#)

**Examples**

```
data(dataMZ)

# define constraints
constr <- data.frame(
  patID=c("P123", "P234"),
  structure=c("HEART", "*"),
  constraint=c("D1CC < 20Gy", "V10% > 8CC"),
  stringsAsFactors=FALSE) # this is important
showConstraint(dataMZ, constr=constr, byPat=FALSE)
```

---

showDVH

*Display dose volume histograms*

---

**Description**

Displays dose volume histograms: Either one diagram per patient - including multiple structures. Or one diagram per structure - including multiple patients.

**Usage**

```
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHs'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHlst'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHlstLst'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)
```

**Arguments**

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHlst), or multiple DVHs from many patients/structures (object of class DVHlstLst). See <a href="#">readDVH</a> . See Details.
cumul	logical. Show cumulative or differential (per unit dose) DVH?
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHlstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
patID	character vector. Show diagram for these patients only. If missing, all patients are shown. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
structure	character vector. Show diagram for these structures only. If missing, all structures are shown. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
rel	logical. Show relative volume?
guessX	logical. Try to guess the best x-axis limits for better visibility of main DVH range? If FALSE, x-axis runs from 0 to maximum dose. If TRUE, x-axis runs from 0 to dose value where volume approaches 0. If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
guessY	logical. Try to guess the best y-axis limits? If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+5%) such that the "highest" DVH is cut off at this relative volume.
addMSD	logical. If TRUE, diagram shows the point-wise mean DVH as well as shaded areas for point-wise 1-standard deviation and 2-standard deviations around this mean. See details.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only <a href="#">ggplot</a> diagram objects are silently returned.
visible	logical. Return <a href="#">ggplot</a> diagram object visibly or invisibly. show=FALSE with visible=TRUE is useful for zooming in shiny apps.
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.

**Details**

If multiple diagrams are produced, they are shown in the same graphics device. If interactive inspection is required, make sure you use an R development environment that saves previous diagrams and allows navigating between them - e.g., [RStudio](#) or [OpenAnalytics Architect](#).

For addMSD=TRUE, the number of DVH nodes (dose values) is reduced by 1/3 of the maximum number of nodes in x. Before calculating the point-wise mean and SD, DVHs in x are first linearly interpolated using the same set of nodes.

**Value**

Silently returns a [ggplot](#) diagram object, or - when multiple diagrams are constructed - a list of [ggplot](#) diagram objects.

**See Also**

[ggplot](#), [readDVH](#), [saveDVH](#), [getMeanDVH](#)

**Examples**

```
showDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))

# matches patients P123 and P234
showDVH(dataMZ, byPat=FALSE, patID="23", fixed=FALSE)
```

---

showMeanDVH

*Show average dose volume histograms*

---

**Description**

Displays average dose volume histograms grouped by patients or structures.

**Usage**

```
showMeanDVH(x, byPat=TRUE, patID=NULL, structure=NULL,
            rel=TRUE, guessX=TRUE, thresh=1, show=TRUE, fixed=TRUE,
            showSD=TRUE, color=TRUE, facet=TRUE)
```

**Arguments**

x	A data frame as returned by <a href="#">getMeanDVH</a> or a list of such data frames.
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHlstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
patID	character vector. Show diagram for these patients only. If missing, all patients are shown. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
structure	character vector. Show diagram for these structures only. If missing, all structures are shown. Can be a regular expression with fixed=FALSE, see <a href="#">regex</a> .
rel	logical. Show relative volume?
guessX	logical. Try to clip the x-axis for better visibility of main DVH range?
thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+10%) such that the "highest" DVH is cut off at this relative volume.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only <a href="#">ggplot</a> diagram objects are silently returned.

fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.
showSD	logical. If TRUE, diagram shows shaded areas for point-wise 1-standard deviation and 2-standard deviations around this mean. See details.
color	logical. If TRUE, diagram uses color to distinguish groups. If FALSE, colors are greyscale, and line types are used to distinguish groups.
facet	logical. If TRUE, different structures (for byPat=FALSE or different patients (for byPat=TRUE go into separate panels using <a href="#">facet_grid</a> ). If FALSE, everything is shown in the same panel.

### Details

TODO

### Value

Silently returns a [ggplot](#) diagram object, or - when multiple diagrams are constructed - a list of [ggplot](#) diagram objects.

### See Also

[ggplot](#), [showDVH](#), [getMeanDVH](#)

### Examples

```
# mean DVH for HEART and AMYOCL averaged over patients
res <- getMeanDVH(dataMZ, byPat=FALSE, structure=c("HEART", "AMYOCL"))
showMeanDVH(res)
```

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