



Healthcare Analytics
Anticoagulation Time in Therapeutic Range Calculation Documentation
September 4, 2015

Reference #1: Percent of Days in Range (Rosendaal Method)

Article: <http://www.inrpro.com/article.asp?id=1>

Example: <http://www.inrpro.com/rosendaal.asp>

Excerpt:

“This is the most complex of the calculations, as it looks at the amount of time between visits to determine how long the patient might have been within their therapeutic range. If a patient has a therapeutic range of 2.0 - 3.0, and on May 1st tested at 2.5, and then tested 3.5 on May 31st, then we can determine how many days were in range. Since there were 30 days between tests, you assume that the patient slowly moved from 2.5 to 3.5 over those 30 days, so around May 15th, the patient was probably over 3.0, and therefore was out of range. Therefore, we estimate that 15 days were in range, and 15 days were out of range (within the 30 day time period), which means the patient is within range 50% of the time.”

Reference #2: Warfarin Time in Therapeutic Range - Supplemental SQL Logic Reference

Link:

http://www.healthit.gov/archive/archive_files/HIT%20Standards%20Committee/2013/Clinical%20Quality/2013-11-14/CMS179v2_UserGuide_SQL_Logic_Reference%20Jun%202013.pdf

Excerpt:

“Warfarin time in therapeutic range is the percent of time in which patients with atrial fibrillation or flutter who are on chronic warfarin therapy have INR test results within the therapeutic range (2.0 - 3.0) during the measurement period.

“The following filters are applied to the INR results prior to the calculation of TTR for each patient:

- 1) INR value closest to 2.5 when there is more than one INR result on a single date**
- 2) INR values greater than 10 will be replaced with an INR value of 10**
- 3) INR values less than 0.8 are ignored and eliminated from the final TTR calculation for each patient**

“The logic keeps track of the number of valid INR intervals for each patient. **A Valid INR Interval is defined as a pair of INR start dates that are less than or equal to 56 days apart. Patients without 2 such intervals will be excluded from the calculation** of the providers’ Average PctTTR later on.”

TTR Calculation Steps

(1) Pull patient INR results using following query:

```
select *, rank () over (partition by MRN order by resultdtm asc, numericresult desc) as rank
into #PatientINR
from
    (select distinct
        organizationMRN as MRN
        , patientid
        , EntryName
        , ResultDTTM
        , case when NumericResult > 10 then 10 else numericresult end as NumericResult
        , case when entrycode = '2113' then 'Facey'
            when entrycode = '9731' then 'Quest'
            when entrycode = '3029' then 'POC'
            else 'Other'
            end as Source
    from [FMFEHRETL01].AHSRelate.dbo.AHS_RESULT a
    inner join [FMFEHRETL01].AHSRelate.dbo.AHS_PATIENT_IORG pt on a.patientID =
        pt.personID

    where a.EntryName like '%INR%'
    and numericresult > 0.8
    and a.organizationid = 3
    and resultdtm > '2012-01-01') A

select A.* from #PatientINR A
inner join sandbox_erubin.dbo.tbl_nvaf_hmo B
on A.MRN = B.u_facey_org_MRN
where patientid in (select patientid from #PatientINR where rank =2)
```

Notes about query:

- Will discard values less than 0.8
- Will only look at values past a specific date (in this case 1/1/2012)
- Will only look at patients with more than one INR result

(2) Paste results into Excel

	A	B	C	D	E	F	G
1							
2	MRN	patientid	EntryName	ResultDTTM	NumericR esult	Source	rank
3			POC INR	1/19/2012	2.8	POC	1
4			POC INR	2/23/2012	3.3	POC	2
5			POC INR	3/9/2012	2.7	POC	3
6			POC INR	4/10/2012	2.9	POC	4
7			POC INR	5/10/2012	2.9	POC	5
8			POC INR	6/11/2012	2.6	POC	6
9			POC INR	7/16/2012	2.9	POC	7
10			POC INR	8/8/2012	2.9	POC	8
11			POC INR	9/13/2012	2.4	POC	9
12			POC INR	10/26/2012	2.7	POC	10
13			POC INR	11/19/2012	2.7	POC	11
14			POC INR	12/19/2012	2.8	POC	12
15			POC INR	1/22/2013	3	POC	13
16			POC INR	2/25/2013	3.1	POC	14
17			POC INR	3/26/2013	2.9	POC	15
18			POC INR	5/1/2013	2.9	POC	16
19			POC INR	6/6/2013	2.2	POC	17
20			POC INR	7/15/2013	3.6	POC	18
21			POC INR	7/24/2013	2.2	POC	19
22			POC INR	8/29/2013	2.5	POC	20
23			POC INR	10/1/2013	3.3	POC	21
24			POC INR	11/1/2013	2.3	POC	22
25			POC INR	11/26/2013	3	POC	23
26			POC INR	12/27/2013	1.7	POC	24
27			POC INR	2/14/2014	1.7	POC	25
28			POC INR	2/28/2014	3.2	POC	26
29			POC INR	3/14/2014	3.9	POC	27
30			POC INR	3/31/2014	3.6	POC	28
31			POC INR	5/6/2014	2.5	POC	29

- (3) Create column for number of days between results
- Use DAYS360 function in Column H (“D”) to calculate number of days between result in previous row and result in current row.
 - Add “IF” functions to formula in order to have “0” value for the first row for each new patient and also replace values over 56 with 0 since intervals over 56 days are not valid.
 - Final formula:

$$=IF(G4=1,0,IF(DAYS360(D3,D4,FALSE)>56,0,DAYS360(D3,D4,FALSE)))$$

ResultDTTM	NumericR result	Source	rank	D
1/19/2012	2.8	POC	1	0
2/23/2012	3.3	POC	2	$=IF(G4=1,0,IF(DAYS360(D3,D4,FALSE)>56,0,DAYS360(D3,D4,FALSE)))$

- Drag down formula and then copy and paste as values.

- (4) Create Column “A” for the “High INR value” and Column “B” for the “Low INR Value”
- If the current result is higher than the previous result (for the row), return the current result as the “High INR,” else return the previous result. Drag down formula.

ResultDTTM	NumericR result	Source	rank	D	High INR A
1/19/2012	2.8	POC	1	0	
2/23/2012	3.3	POC	2	34	$=IF(E4>E3,E4,E3)$
3/9/2012	2.7	POC	3	16	$IF(logical_test, [value_if_true], [value_if_false])$

- If the current result is higher than the previous result (for the row), return the previous result as the “Low INR,” else return the current result.
- Drag down formula

NumericR result	Source	rank	D	High INR A	Low INR B
2.8	POC	1	0		
3.3	POC	2	34	3.30	$=IF(E4>E3,E3,E4)$
2.7	POC	3	16	3.30	$IF(logical_test, [value_if_true], [value_if_false])$

(5) Create Column “(A-B)/D” for the total change between the INR results divided by the number of days between the INR results is the “Change per Day.”

- Note: If the value of **D** is 0, this will result in a “divide-by-zero error” and the rest of the calculations to arrive at the TTR will not be made. This is desirable since we do not want to calculate TTR for invalid intervals.
- Drag down formula

			High INR	Low INR	Change per day	
Source	rank	D	A	B	(A-B)/D	
POC	1	0				
POC	2	34	3.30	2.8	=ABS(I4-J4)/H4	
POC	3	16	3.30	2.7	ABS(number)	

(6) Create Columns for “Days out of Range on Low End” and “Days out of Range on High End” in columns L and M

F	G	H	I	J	K	L	M
			High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end
Source	rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]

a. Days out of Range on Low End = $(2 - B) / \left[\frac{A-B}{D} \right]$

b. Days out of Range on High End = $(A - 3) / \left[\frac{A-B}{D} \right]$

(7) Insert formulas for calculations

D	E	F	G	H	I	J	K	L	M	N
					High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end	
ResultDTTM	NumericR result	Source	rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]	
1/19/2012	2.8	POC		1	0					
2/23/2012	3.3	POC		2	34	3.30	2.8	0.014706	=IFERROR(IF(AND(K4=0,E4<2),H4,(2-J4)/K4),0)	
3/9/2012	2.7	POC		3	16	3.30	2.7	0.0375	IFERROR(value, value_if_error)	

a. For Days out of Range on Low End (in column L):

$$=IFERROR(IF(AND(K4=0,E4<2),H4,(2-J4)/K4),0)$$

- This formula performs the operation $(2 - B) / \left[\frac{A-B}{D} \right]$
- $(2-B)$ = (2 minus the low INR value) which will account for any movement from *below* the therapeutic range into the therapeutic range
- Dividing the change between “under” the therapeutic range into the therapeutic range by the total change per day equals the total number of days “under” the therapeutic range
- Remember – the Rosendaal Method assumes consistent change per day throughout the INR Interval between results
- Example:

(Please note the INR result is a ratio and thus has no units.)

A valid INR interval consists of an INR result of 3.0 on 11/26/2013 and an INR result of 1.7 on 12/27/2013.

Thus, the high INR for the interval (A) = 3.0 and the low INR for the interval (B) = 1.7.

The total change for the interval is $(A - B) = (3.0 - 1.7) = 1.3$

The number of days is from 11/26/2013 – 12/27/2013 which is 31 days.

The Change per Day is $\frac{A-B}{D} = \frac{1.3}{31 \text{ days}} \approx 0.041935/\text{day}$

The amount of change between “under” the therapeutic range into the therapeutic range is $(2 - B) = 2 - 1.7 = 0.3$ because everything between 2 and 3 is in the therapeutic range.

The number of days out of range on the low end = the change from under the range into the range divided by the change per day:

$$\frac{2-1.7}{0.041935/\text{day}} = \frac{0.3}{0.041935} \text{ days} \approx 7.154 \text{ days}$$

D	E	F	G	H	I	J	K	L	M
					High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end
ResultDTTM	NumericR result	Source	rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]
12/27/2013	1.7	POC	24	31	3.00	1.7	0.041935	7.153846154	0

b. For **Days out of Range on High End** (in column M):

=IFERROR(IF(AND(K4=0,E4>3),H4,((I4-3)/K4)),0)

- This formula performs the operation $(A - 3) / \left[\frac{A-B}{D} \right]$

- (A-3) = (the high INR value minus 3) which will account for any movement from *above* the therapeutic range into the therapeutic range
- Dividing the change between “above” the therapeutic range into the therapeutic range by the total change per day equals the total number of days “above” the therapeutic range
- Remember – the Rosendaal Method assumes change per day is consistent throughout the INR Interval
- Example

(Please note the INR result is a ratio and thus has no units.)

A valid INR interval consists of an INR result of 2.8 on 1/19/2012 and an INR result of 3.3 on 2/23/2012.

Thus, the high INR for the interval (A) = 3.3 and the low INR for the interval (B) = 2.8.

The total change for the interval is (A – B) = (3.3 – 2.8) = 0.5

The total number of days is from 1/19/2012 – 2/23/2012 which is 34 days.

The Change per Day is $\frac{A-B}{D} = \frac{0.5}{34 \text{ days}} \approx 0.014706/\text{day}$

The amount of change between “above” the therapeutic range into the therapeutic range is (A – 3) = 3.3 – 3 = 0.3 because everything between 2 and 3 is in the therapeutic range.

The number of days out of range on the high end = the change from above the range into the range divided by the change per day:

$$\frac{3.3-3}{0.014706/\text{day}} = \frac{0.3}{0.014706} \text{ days} \approx 20.4 \text{ days}$$

D	E	F	G	H	I	J	K	L	M
					High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end
ResultDTTM	NumericR result	Source	rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]
1/19/2012	2.8	POC	1	0					
2/23/2012	3.3	POC	2	34	3.30	2.8	0.014706		20.4

c. Drag down formulas

d. Notes:

- If the Low INR is > 2 then the value in column L will be negative. This simply indicates there was no movement below the therapeutic range.
- Likewise, if the High INR is < 3, the value in column M will be negative. This indicates there was no movement above the therapeutic range.

iii. Negative values will be treated as zero values in our final calculations

(8) Create column for **Days in Therapeutic Range**

- The complete formula is $[D - (2 - B) / \frac{A-B}{D}] - (A - 3) / \frac{A-B}{D}$, which is just the total number of days in the interval minus the days out of range on each end.
- Nested "IF" functions were used in the formula for column N to make the calculation:

=IF(G4=1,0,IF(IF(AND(L4<0,M4<0),H4,IF(L4<0,(H4-M4),IF(M4<0,(H4-L4),(H4-M4-L4))))<0,0,IF(AND(L4<0,M4<0),H4,IF(L4<0,(H4-M4),IF(M4<0,(H4-L4),(H4-M4-L4))))))

			High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end	Days in Therapeutic Range
Source	rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]	D - (2-B)/[(A-B)/D] - (A-3)/[(A-B)/D]
POC	1	0						0
POC	2	34	3.30	2.8	0.014706	-54.4	20.4	=IF(G4=1,0,IF(IF(AND(L4<0,M4<0),H4,IF(L4<0,(H4-M4),IF(M4<0,(H4-L4),(H4-M4-L4))))<0,0,IF(AND(L4<0,M4<0),H4,IF(L4<0,(H4-M4),IF(M4<0,(H4-L4),(H4-M4-L4))))))
POC	3	16	3.30	2.7	0.0375	-18.66666667	8	
POC	4	31	2.90	2.7	0.006452	-108.5	-15.5	

Note:

Most of the calculations so far have been done in the second record because the first record does not have a previous value.

The next calculations aggregate the TTR for each patient. They will be done in the first record and, using "IF" statements, they will be repeated when the value in column G (rank) is equal to 1 (once per patient).

(9) Create column for **Patient Days TTR** (Number of days for each patient in therapeutic range)

- This formula will sum the days between intervals in the therapeutic range for a total number of days in the therapeutic range
- The formula says: if the "rank" = 1, sum all the columns where the patient MRN equals the MRN in this record. If the rank ≠ 1, then return nothing.

=IF(G3=1,SUMIF(A:A,A3,N:N),"") - Where column A contains the MRN and cell A3 is the row where the rank = 1.

G	H	I	J	K	L	M	N	P
		High INR	Low INR	Change per day	Days out of range on low end	Days out of range on high end	Days in Therapeutic Range	
rank	D	A	B	(A-B)/D	(2-B)/[(A-B)/D]	(A-3)/[(A-B)/D]	D - (2-B)/[(A-B)/D] - (A-3)/[(A-B)/D]	PATIENT DAYS TTR
1	0						0	598.071695
2	34	3.30	2.8	0.014706	-54.4	20.4	13.6	

c. Drag down formula.

- (10) Create column for **Patient TTR %** (*Percentage of days for each patient in therapeutic range*)
- This formula will divide the total number of days in therapeutic range by the total number of days between all valid intervals. This is not the same as the number of days between the first and last result, as a valid interval is defined as 56 days between results.
 - TTR % = (Total Days in Therapeutic Range)/(Total Days in Valid Intervals) x 100%**
 - This formula uses the same “IF” logic as the previous formula

=IF(G3=1,SUMIF(B:B,B3,N:N)/SUMIF(B:B,B3,H:H),"")

d. Drag down formula

rank	D	High INR A	Low INR B	Change per day {A-B}/D	Days out of range on low end {2-B}/[{A-B}/D]	Days out of range on high end {A-3}/[{A-B}/D]	Days in Therapeutic Range D- (2-B)/[{A-B}/D] - (A-3)/[{A-B}/D]	PATIENT DAYS TTR	PATIENT TTR %
1	0						0	598.071695	=IF(G3=1,SUMIF(B:B,B3,N:N)/SUMIF(B:B,B3,H:H),"")
2	34	3.30	2.8	0.014706	-54.4	20.4	13.6		

- (11) Clean up the data
- Paste values into separate workbook to decrease file size
 - Filter results by column P or Q to eliminate blanks
 - Hide unnecessary columns
 - Paste values into separate worksheet resulting in one TTR % for each patient

1	MRN	PATIENT DAYS TTR	PATIENT TTR %
2		569.3261905	0.79073082
3		31.45849802	0.179762846
4		689.559044	0.701484277
5		345.4049614	0.549133484
6		430.7969772	0.535151524
7		368.2232557	0.543102147
8		579.4450216	0.823075315
9		5.5	0.152777778
10		304.9487179	0.680689103
11		806.7531634	0.626361152
12		547.6953813	0.63464123