Physician‘s Guide

for the Hannover ECG System

HES®

Institute for
Medical Diagnostics

(Version 1.0, 26.01.2006 for HES Kernel 24-03)

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0 Introduction

This guide describes the criteria that the HES ECG Analysis Program uses to analyse and provide interpretative statements for 12-lead ECGs.

Interpretative statements have two components, the actual interpretative text, and the optional reason statement, which immediately follows in each statement in this Physician's Guide, and which provides a synopsis of the principle criteria used to reach the specified conclusion. The intention is to provide these reason statements where users find them helpful.

Interpretation of all ECGs proceeds in the sequence of the criteria listing. Ordinarily the last valid statement or conclusion reached within a given section supplants all prior statements.

The interpretative output text of the HES program contains the following sections:

- General measurements
- Rhythm analysis
- Technical hints
- Specific findings
- QRS-T evaluation
- Summary (or Bottom line statement)

The following chapters describe the schemes or thresholds for setting specific output statements. This document does not describe:

- Schemes of pure measurement output (e.g. hr)
- Fixed output Statements (like headings or version information)

1 General measurements

In this output statement section measurements for the hr, P wave duration, PR interval, QRS duration, QT duration QTc duration, rel. QT, Frontal vectors for P-, QRS-, T-waves and QRS frontal vector typing are printed out. For “abnormal” measurements the character “*” is set. The following ECG specific statements may be set by the program:

- tachycardia (see 1.1)
- tachycardia for age (see 1.1)
- bradycardia (see 1.1)
- bradycardia for age (see 1.1)
- *P (=abnormal P duration), if P duration > 128 ms
- *PR (=abnormal PR duration), if PR interval > 200 ms or PR segment < 20 ms
- *QRS (=abnormal QRS duration) see 1.2
- *QTr (=abnormal rel. QT duration), if QTr < 90 % or QTr > 114%
- QRS frontal vector typing (see 1.3)

1.1 Tachycardia/Bradycardia

Age in years	hr >	Statement	hr <	Statement
1	175	tachycardia for age	110	bradycardia for age
2	165	tachycardia for age	105	bradycardia for age
3	155	tachycardia for age	100	bradycardia for age
4	145	tachycardia for age	90	bradycardia for age
5	135	tachycardia for age	85	bradycardia for age
6	130	tachycardia for age	80	bradycardia for age
7	125	tachycardia for age	75	bradycardia for age
8	120	tachycardia for age	70	bradycardia for age
9	120	tachycardia for age	70	bradycardia for age
10	115	tachycardia for age	70	bradycardia for age
11	115	tachycardia for age	70	bradycardia for age
12	110	tachycardia for age	70	bradycardia for age
13	110	tachycardia for age	65	bradycardia for age
14	105	tachycardia for age	65	bradycardia for age
15	105	tachycardia	65	bradycardia
>15	100	tachycardia	60	bradycardia

1.2 Abnormal QRS duration

Age in years	QRS dur. in ms >	Statement
1	80	*QRS
2	80	*QRS
3	85	*QRS
4	85	*QRS
5	85	*QRS
6	90	*QRS
7	90	*QRS
8	90	*QRS
9	95	*QRS
10	95	*QRS
11	95	*QRS
> 11	100	*QRS

1.3 QRS frontal vector typing

The HES ECG Analysis program provides two different schemes for QRS frontal vector typing. The current scheme is selected by a control variable (see current version of the Technical documentation).

1.3.1 The default QRS frontal vector typing

Type	Describtion	Criteria
8	Sagittal pattern	(R amplitude in I,II and III > 500 µV and S wave present in I, II and III) or (80% < R/S in I,II and III < 120%)
9	SI/QIII pattern	Not type 8 and S dur. in I >= 30ms and S ampl. in I >= 150µV and Q dur. in III >= 30ms and Q ampl in III >= 150µV and Q dur. in III >= (R dur. in III)/4
11	QIII-left-axis-pattern	Not type 8-9 and R ampl. in I > R ampl. in II > R ampl. in III and Q ampl. in III > R ampl. in III and no Q wave in II
5	Left axis deviation	(Frontal vector QRS angle <= 30 ° or QRS angle >= 330 °) and not type 8-11
4	Indifferent axis	Frontal vector QRS angle > 30 ° and not type 8-11
3	Vertical axis	Frontal vector QRS angle > 60 ° and not type 8-11
2	Right axis deviation	Frontal vector QRS angle > 90 ° and not type 8-11
1	Extreme right axis deviation	Frontal vector QRS angle > 120 ° and not type 8-11
7	QRS angle < -90 degree	Frontal vector QRS angle > 180 ° and not type 8-11
6	Extreme left axis deviation	Frontal vector QRS angle >= 270 ° and not type 8-11
10	QI/SIII pattern	Current type 1-7 and Q dur. in I >= 30ms and S dur. in III >= 30ms and TEST1 is true
12	-	Current type 8-11 and Q dur. in I >= 30ms and S dur. in III >= 30ms and TEST1 is true
		TEST1 is true if (R/S in V1 > 100% and abs. S ampl. in V1 > 40µV) or (R/S in V2 > 100% and abs. S ampl. in V2 > 40µV) or (R/S in V3 > 100% and abs. S ampl. in V3 > 40µV)

1.3.2 The QRS frontal vector typing for USA

For this coding scheme the QRS Frontal angle is internal set into a range from –180° to +180°.

Type	Describtion	Criteria
109	SI/QIII pattern	S dur. in I >= 30ms and Q dur. in III >= 30ms and Q dur. in III >= R dur. in III/4
101	Indeterminate axis	Type is not 109 and -180° <= QRS frontal angle < -90°
102	Left axis deviation	Type is not 109 and -90° <= QRS frontal angle < -30°
103	Normal axis	Type is not 109 and -30° <= QRS frontal angle < 105°
104	Right axis deviation	Type is not 109 and 105° <= QRS frontal angle < 180°
110	QI/SIII pattern	Q dur. in I >= 30ms and S dur. in III >= 30ms and ((R/S in V1 > 100% and abs. S ampl. in V1 > 40µV) or (R/S in V2 > 100% and abs. S ampl. in V2 > 40µV) or (R/S in V3 > 100% and abs. S ampl. in V3 > 40µV))

2 Rhythm-analysis

The rhythm analysis is based on the QRS-morphology of the single detected beats and the respective rr intervals between these beats.

3 Technical hints

Statement	Criteria
noise XX µV small	High frequency noise in the raw data (RMS) < 15µV
noise XX µV medium	15µV<= High frequency noise in the raw data (RMS) <= 30µV
noise XX µV high check ECG - repeat recording	High frequency noise in the raw data (RMS) > 30µV
baseline shift XXXX µV	max. baseline shift in one lead > 300 µV
consider artificial ECG	Score of test for artificial ECG <= 6
high offset in:	Leads with more then 75% of the beats with QRS basepoints > 1800 µV
high amplitude in:	Leads with an abs. ampl. from QRSon to QRSon+100ms in at least one beat > 5000µV
questionable ECG measurement in X lead(s) no further evaluation	Number of dubious measurements in one lead >= 4 (P wave present) or >= 3 (No P wave): - abs. P ampl. < 50µV - abs. Q ampl. + R ampl. < 80µV - R ampl. + abs. S ampl. < 80µV - max. abs. T ampl. < 100µV or (abs. Q ampl. < 160µV and R ampl. < 160µV and abs. S ampl. < 160 µV and abs. P max. ampl. >= 160µV and abs. Tmax. ampl >= 160µV) The statement is skipped if: - Only one lead is marked as unplausible and pos. and neg. T ampl. >= 100µV and abs. ST ampl. > 800µV.
probably limb leads reversed	The following parameters will be used: - Correlation coefficients of 12 QRS instantaneous measurements and 8 T instantaneous measurements for I/V6, -aVR/6 and aVL/V6 correlation - sign of the P wave extrema in lead I and aVR - integrals P, QRS and T and R ampl. in the leads I and V5
low voltage in limb leads, total QRS< 0.5 mV	Range of QRS amplitudes in all limb leads < 500µV
low voltage in chest leads leads, total QRS< 1.0 mV	Range of QRS amplitudes in all chest leads < 1000µV
less than X of YY cycles averaged check ECG - repeat recording	Less than 20% of the detected cycles or less than 2 cycles averaged
P-QRS fusion questionable ECG measurement and interpretation	If in at least 2 leads: (the amplitude difference between Ponset and Poffset is >=150µV and PR segm. >= 16ms) or (the amplitude difference between Ponset and Poffset is >= 90µV and PR segm. < 16ms) or (the slope before QRSonset is >= 100 and PR segment >= 16ms) or (the slope before QRSonset is >= 40µV and PR segment < 16ms)
possible TP fusion P and T wave recognition questionable questionable ECG measurement and interpretation	if (a hidden P wave is detected and the mean rr interval is > 500ms and 1.2*mean rr >= PT interval and the PR interval is >= 200ms) or if (no hidden P wave is detected and 1.1*mean rr < PT interval and the PQ interval is < 200ms)
PQ+QT > RR: Check Pon and Toff fiducials	PQ-interval+QT-Interval > mean rr interval

4 Specific findings

Table 1 of 3 for specific findings

Statement	Criteria
short PR segment	No WPW and PR segment <= 20ms
broad QRS	if age > 16 years and male and QRS-duration > 115ms if age > 16 years and female and QRS-duration > 105ms if age 12-16 years and QRS-duration > 115ms if age 9-11 years and QRS-duration > = 110ms if age 6-8 years and QRS-duration > 105ms if age 3-5 years and QRS-duration >= 100ms if age 1-2 years and QRS-duration > 95ms
high voltage QRS	Def.: Sokolov_index= max.((abs. S ampl. V1 + R ampl. V5) and (abs. S ampl. V2 + R ampl. V6)) If age 14-29 years and Sokolov_index >= 4000µV If age 30-49 years and Sokolov_index >= 3600µV If age >=50 years and Sokolov_index >= 3000µV
M form in :	if R1 ampl. > 300µV and R2 ampl. > 300µV
tall R' in :	Statement "M form in: " is not set and R1 ampl. >= 80µV and abs. S1 ampl. > 50µV and R2 ampl. > 300µV
late R in :	Only for leads aVR, V1 and V2 and only if statement "tall R' in:" is not set !!! if (Q dur. >= 30ms and abs. Q ampl. >= 200µV and R ampl. > 300µV) or (R1 ampl. < 50µV and abs. S1 ampl. > 200µV and R2 ampl. > 300µV and abs. ampl. S2 < 50µV)
broad R in:	If R1 ampl > 300 µV and R1 dur. >= 80ms (for I, III, aVL, V3, V4, V5 and V6) >= 120ms (for II and aVF) >= 55ms (for aVR) >= 45ms (for V1) >= 60ms (for V2)
ST depression in:	if ST ampl < -100µV and (lead is II, III, aVR, aVF, V1 or V2) or (lead is I, aVL, V3-V6 and no endocardial repolarization disturbances higher 2nd degree)
ST elevation in:	if ST ampl. > 100µV (limb lead) or if ST ampl. > 300µV (lead V1-V3) or if ST ampl. > 200µV (lead V4-V6)
broad S in:	if S dur.>= 55ms (lead I, II, V4 and V5) if S dur.>= 150ms (lead III, aVR, aVL, aVF, V1 and V2) if S dur.>= 65ms (lead V3) if S dur.>= 50ms (lead V6)
broad R' in:	Only leads aVR, V1 and V2 !!! if (R1 ampl. > 50µV) and (R2 dur. > 55 ms in aVR or R2 dur. > 45 ms in V1 or R2 dur. > 60 ms in V2

Table 2 of 3 for specific findings

Statement	Criteria
Q in:	Lead I: if (abs. Q ampl. > 180µV or Q dur. > 30ms) and (abs. Q ampl. > 500µV or no R) Lead II: if (abs. Q ampl. > 200µV or Q dur. > 30ms) and (abs. Q ampl. > 500µV or no R) Lead III: if (abs. Q ampl. > 350µV or Q dur. > 45ms) and (abs. Q ampl. > 500µV or no R) Lead aVR: if(abs. Q ampl. > 1200µV or Q dur. >150ms) and (abs. Q ampl. > 500µV or no R) Lead aVL: if(abs. Q ampl. > 200µV or Q dur. > 40ms) and (abs. Q ampl. > 500µV or no R) Lead aVF: if(abs. Q ampl. > 200µV or Q dur. > 35ms) and (abs. Q ampl. > 500µV or no R) Lead V1: if(abs. Q ampl. > 20µV or Q dur. > 20ms) and (abs. Q ampl. > 500µV or no R) Lead V2: if(abs. Q ampl. > 20µV or Q dur. > 20ms) and (abs. Q ampl. > 500µV or no R) Lead V3: if(abs. Q ampl. > 90µV or Q dur. > 20ms) and (abs. Q ampl. > 500µV or no R) Lead V4: if(abs. Q ampl. > 200µV or Q dur. > 25ms) and (abs. Q ampl. > 500µV or no R) Lead V5: if(abs. Q ampl. > 230µV or Q dur. > 30ms) and (abs. Q ampl. > 500µV or no R) Lead V6: if(abs. Q ampl. > 230µV or Q dur. > 30ms) and (abs. Q ampl. > 500µV or no R)
QS in :	Statement "Q in: " is not set for the lead and no R wave present and: Lead I: if abs. Q ampl. > 180µV Lead II: if abs. Q ampl. > 200µV Lead III: if abs. Q ampl. > 350µV Lead aVR: if abs. Q ampl. > 1200µV Lead aVL: if abs. Q ampl. > 200µV Lead aVF: if abs. Q ampl. > 200µV Lead V1: if abs. Q ampl. > 20µV Lead V2: if abs. Q ampl. > 20µV Lead V3: if abs. Q ampl. > 90µV Lead V4: if abs. Q ampl. > 200µV Lead V5: if abs. Q ampl. > 230µV Lead V6: if abs. Q ampl. > 230µV
tall R in :	If statements "tall R' in:" and "broad R in:" are not set and Lead I: R1 ampl. > 1500µV Lead II: R1 ampl. > 2100µV Lead III: R1 ampl. > 1700µV Lead aVR: R1 ampl. > 360µV Lead aVL: R1 ampl. > 1100µV Lead aVF: R1 ampl. > 1900µV Lead V1: R1 ampl. > 750µV Lead V2: R1 ampl. > 1700µV Lead V3: R1 ampl. > 2400µV Lead V4: R1 ampl. > 3000µV Lead V5: R1 ampl. > 2800µV Lead V6: R1 ampl. > 2100µV
deep S in :	Lead I: abs. S ampl. > 480µV Lead II: abs. S ampl. > 480µV Lead III: abs. S ampl. > 950µV Lead aVR: abs. S ampl. > 1500µV Lead aVL: abs. S ampl. > 900µV Lead aVF: abs. S ampl. > 500µV Lead V1: abs. S ampl. > 2100µV Lead V2: abs. S ampl. > 3100µV Lead V3: abs. S ampl. > 2400µV Lead V4: abs. S ampl. > 1600µV Lead V5: abs. S ampl. > 800µV Lead V6: abs. S ampl. > 350µV

Table 3 of 3 for specific findings

Statement	Criteria
R loss or reduction in :	Not in leads aVR and V1; only if R wave is present: if R ampl. < 100µV
reduced R in:	For limb leads: Lead I: if 100µV <= R ampl. <= 250µV and no LowVoltageInLimbLeads is set Lead II: if 100µV <= R ampl. <= 350µV and no LowVoltageInLimbLeads is set **LowVoltageInLimbLeads** is set if in leads I-III no (R ampl.+abs.Q ampl.) >= 500µV and no (R ampl.+ abs. S ampl.) >= 500µV For chest leads: Lead V2: if 100µV <= R ampl. <= 150µV and no LowVoltageInChestLeads is set Lead V3: if 100µV <= R ampl. <= 250µV and no LowVoltageInChestLeads is set Lead V4: if 100µV <= R ampl. <= 450µV and no LowVoltageInChestLeads is set Lead V5: if 100µV <= R ampl. <= 750µV and no LowVoltageInChestLeads is set Lead V6: if 100µV <= R ampl. <= 550µV and no LowVoltageInChestLeads is set **LowVoltageInChestLeads** is set if in leads V1-V6 no (R ampl.+abs.Q ampl.) >= 1000µV and no (R ampl.+ abs. S ampl.) >= 1000µV
small S in:	Lead aVR: if 20µV <= abs. S ampl. < 500µV and no LowVoltageInLimbLeads is set Lead V1: if 20µV <= abs. S ampl. < 300µV and no LowVoltageInChestLeads is set Lead V2: if 20µV <= abs. S ampl. < 300µV and no LowVoltageInChestLeads is set
abnormal R/S in :	Lead V1 and sex is male: R ampl. > 500µV and |S ampl.| > 500µV and R/|S| > 85% Lead V1 and sex is female: R ampl. > 500µV and |S ampl.| > 500µV and R/|S| > 65% Lead V2 and sex is male: R ampl. > 500µV and |S ampl.| > 500µV and R/|S| > 180% Lead V2 and sex is female: R ampl. > 500µV and |S ampl.| > 500µV and R/|S| > 150%
no QRS-T evaluation because of reversed limb electrodes	The following parameters are used: - Correlation coefficients of 12 QRS instantaneous measurements for I/V6, -aVR/6 and aVL/V6 correlation - Correlation coefficients of 8 T instantaneous measurements for I/V6, -aVR/6 and aVL/V6 correlation - sign of the P wave extrema in lead I and aVR - integrals P, QRS and T and R ampl. in the leads I and V5

5 QRS-T evaluation

The QRS-T evaluation, the repolarisation output, the P wave diagnostic and the bundle branch block diagnostic of the HES program uses sets of multivariate statistical tests for getting the diagnosis (see User manual), so it is not possible to present used thresholds.

6 Summary

There are 13 possible output statements for the summary:

Statement	Criteria
abnormal rhythm, otherwise normal ECG	See the bottom line algorithm
normal ECG	See the bottom line algorithm
possible normal ECG	See the bottom line algorithm
indeterminate ECG	See the bottom line algorithm
possible abnormal ECG	See the bottom line algorithm
abnormal ECG	See the bottom line algorithm
pacemaker ECG	All detected QRS-complexes are triggered by pacemaker
abnormal rhythm, otherwise normal ECG with pacemaker	The bottom line algorithm detected "abnormal rhythm, otherwise normal ECG" and there are detected pacemaker spikes, which triggers P- or QRS.
normal ECG with pacemaker	The bottom line algorithm detected "normal ECG" and there are detected pacemaker spikes, which triggers P- or QRS.
possible normal ECG with pacemaker	The bottom line algorithm detected "possible normal ECG" and there are detected pacemaker spikes, which triggers P- or QRS.
indeterminate ECG with pacemaker	The bottom line algorithm detected "indeterminate ECG" and there are detected pacemaker spikes, which triggers P- or QRS.
possible abnormal ECG with pacemaker	The bottom line algorithm detected "possible abnormal ECG" and there are detected pacemaker spikes, which triggers P- or QRS.
abnormal ECG with pacemaker	The bottom line algorithm detected "abnormal ECG" and there are detected pacemaker spikes, which triggers P- or QRS.

6.1 The Bottom line algorithm

The Bottom Line algorithm contains for steps to select one of the six following statements:

- normal ECG
- possible normal ECG
- indeterminate ECG
- possible abnormal ECG
- abnormal ECG
- abnormal rhythm, otherwise normal ECG

The algorithm contains four steps (for details see table on the next page), which check

- infarctions
- hypertrophy
- bundle branch blocks
- wpw
- repolarization disturbances
- ST-T abnormalities
- atrial fibrillation/flutter
- VES
- exchanged limb leads

Step	Criteria	Bottom-Line-Status
Step1: Check for diagnostic code/grade	If the diagnostic code is "Normal" and the grade is > "Possible"	Set "normal ECG" and go to Step2
	If the diagnostic code is "Normal" and the grade is <= "Possible"	Set "possible normal ECG" and go to Step2
	If the diagnostic code is **not** "acute infarction" or "recent infarction" or "left ventricular hypertrophy and ST-T abnormalities" or "left ventricular hypertrophy biventricular hypertrophy possible" and grade is "Check for"	Set "indeterminate ECG" and go to Step2
	If the diagnostic code is **not** "acute infarction" or "recent infarction" or "left ventricular hypertrophy and ST-T abnormalities" or "left ventricular hypertrophy biventricular hypertrophy possible" and grade is "Possible"	Set "possible abnormal ECG" and go to Step2
	All other diagnostic codes/grades (= default)	Set "abnormal ECG" and go to Step2
Step2: Check for bundle branch blocks	If the Bottom-Line-Status of Step1 is "normal ECG" and an incomplete left bundle branch block with grade >= "Probably" is detected	Set "possible normal ECG"
	If an intraventricular conduction defect or a complete left bundle branch block or a complete right bundle branch block is detected and the grade is >= "Probably"	Set "abnormal ECG"
	If the Bottom-Line-Status of Step1 is **not** "abnormal ECG" and an intraventricular conduction defect or a complete left bundle branch block or a complete right bundle branch block is detected and the grade is "Possible"	Set "possible abnormal ECG"
	Default	No change of the Bottom-Line-Status
Step3: Check for wpw, repolarization disturbances and ST elevation	If WPW is detected with a grade >= "Probably" is detected or endocardial repolarisation disturbances grade 2-4 are detected or epicardial repolarisation disturbances grade 3-4 are detected or (endocardial repolarisation disturbances grade 1 is detected and the Bottom-Line-Statement of Step2 is "normal ECG" and the statement "ST elevation in:" is set) or (endocardial repolarisation disturbances grade 1 is detected and the Bottom-Line-Statement of Step2 is **not** "normal ECG")	Set "abnormal ECG" and go to Step4
	If WPW is detected with a grade < "Probably" is detected or (epicardial repolarisation disturbances with unknown grade is detected and the Bottom-Line-Statement of Step2 is **not** "normal ECG") or endocardial repolarisation disturbances grade 2 is detected	Set "possible abnormal ECG" and go to Step4
	If epicardial repolarisation disturbances grade 1 is detected and the Bottom-Line-Statement of Step2 is "normal ECG" and the statement "ST elevation in:" is **not** set	Set "indeterminate ECG" and go to Step4
	If epicardial repolarisation disturbances grade unknown is detected and the Bottom-Line-Statement of Step2 is "normal ECG"	Set "possible normal ECG" and go to Step4
	Default	No change of the Bottom-Line-Status
Step4: Check for atrial fibrillation/flutter, VES and exchanged limb leads	(If atrial fibrillation/flutter is detected or if at least one VES is detected) and the Bottom-Line-Statement of Step3 is **not** "normal ECG"	Set "abnormal ECG"
	(If atrial fibrillation/flutter is detected or if at least one VES is detected) and the Bottom-Line-Statement of Step3 is "normal ECG"	Set "abnormal rhythm, otherwise normal ECG"
	If statement "probably limb leads reversed" is set	Set "abnormal ECG"