ECG Reading Method

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The pediatric ECG reading method is based on the fact that the morphology of a normal ECG varies with age. The electrical activity of the heart reflects hemodynamic cardiac changes, which are at their height in the first month of life and which continue, in part, through the first year of life and beyond.

The general guideline is: a normal pediatric ECG is one in which the morphology is congruous with the age of the young patient. Attention must be paid to the morphology of ventricular depolarization (the QRS complex) and of ventricular repolarization (the T wave). The morphology of these two elements, which change mainly during the first few months of life, should be in accordance with the age of the patient.

Three patterns can be distinguished through the morphology of the QRS complex and the T wave:

- The neonatal pattern.
- The infant pattern.
- The adult pattern.

The neonatal pattern ECG is typical in the first month of life. In a normal subject, this changes after the first month and takes on the characteristics of the infant pattern, which can last up to the age of three. After this point, it changes again, taking on the characteristics of the adult pattern.

Normally, the ECG pattern is in line with the age of the patient. Finding an ECG pattern that is incongruous with the patient's age, for example a neonatal pattern after the first month of life, leads to the conclusion that there is pathological reason. Thus, a series of ECGs conducted on the same patient over time can be very useful to pinpoint the emergence of pathological signs.

It is useful to specify that the terms "newborn" and "infant" are not equivalent to the "neonatal" and "infant" ECG patterns. There is a temporal correspondence between a "newborn", i.e. a child in the first month of life, and a "neonatal ECG pattern", which occurs only in the first month of life for normal subjects. This is not the case, however, for the term "infant", referring to a child in the first year of life, and the term "infant ECG pattern", which can occur at birth and last until the age of three.

1.1 The Neonatal Pattern

A normal ECG from birth and through the first month of life has some characteristics that identify it as the "neonatal pattern". The neonatal pattern shows prevalent electrical

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Table 1.1 Neonatal pattern. Ventricular depolarization. The electrical prevalence of the right ventricle is the norm for newborns

QRS – Neonatal pattern	
In V_1 R wave dominates in that R/S > 1	(R/S ratio: from 1 to 7) (R wave < 25 mm) (S wave < 20 mm)
In V_6: S wave dominates in that R/S < 1	(S wave < 10 mm)
In V_1: if R wave is exclusive	< 13 mm in the 1st week of life < 10 mm after 1st week of life

activity in the right ventricle. This prevalence is normal for newborns since it resembles the hemodynamic condition of a fetus. After the 31st week of gestation until term, the right ventricle of the fetus gains myocardial mass because it pumps against the high resistance of the small muscular pulmonary arteries. The left ventricle, on the other hand, pumps against the low resistance of the placenta's blood vessels. At birth the mass difference between the right and left ventricles is a ratio of 1 to 1.3.

To define the neonatal pattern, two factors present in precordial leads are considered: 1) depolarizing electrical ventricular activity, that is the morphology of the QRS complex; and 2) repolarizing activity, that is the morphology of the T wave. It is sufficient to simply focus on two precordial leads: V_1 and V_6.

The V_1 precordial lead is the one facing the right ventricle. Thus, in the QRS complex, the R wave (the positive deflection) represents the depolarizing electrical activity of the right ventricle. Meanwhile, the S wave (the negative deflection) represents the depolarizing electrical activity of the left ventricle.

The V_6 precordial lead is the one facing the left ventricle. Thus in the QRS complex, the R wave (the positive deflection) corresponds to the depolarizing electrical activity of the left ventricle. Meanwhile, the S wave (the negative deflection) represents the depolarizing electrical activity of the right ventricle.

Since the electrical activity of the right ventricle prevails in the first month of life, the normal neonatal ECG pattern shows the prevalence of the electrical forces of the right ventricle. In the V_1 precordial lead the R wave is dominant over the S wave in that R/S > 1 (the R wave in V_1 represents the depolarizing electrical activity of the right ventricle). In the V_6 precordial lead the S wave is dominant over the R wave in that R/S < 1 (the S wave in V_6 represents the depolarizing electrical activity of the right ventricle). In V_1, the R wave can be exclusive, but its voltage should be less than 13 mm (1.3 mV) in the first week of life and 10 mm (1 mV) afterwards (see Table 1.1).

With regards to repolarizing ventricular electrical activity, that is the morphology of the T wave, the neonatal pattern in the first week of life can have positive or negative T waves in V_1 and positive T waves in V_6, but a flat or negative T wave in V_6 should be considered at the limits of the norm. After the first week of life the neonatal pattern requires the T wave to be negative in the V_1 and V_2 precordial leads and positive in V_6 (see Table 1.2).

A positive T wave in V_1 after the first week of life should be regarded with suspicion and investigated because it has been used to indicate right ventricular hypertrophy. In fact, changes in the T wave in V_1–V_2 are correlated with systolic pressure in the right ventricle and thus correlate with changes in pulmonary vascular resistance (PVR). A positive T wave after the first week of life suggests PVR is

Table 1.2 Neonatal pattern. Ventricular repolarization

T WAVE – Neonatal pattern
In the 1st week of life: • In V_1: positive/diphasic/negative T wave • In V_6: positive/ flat/ negative T wave
After 1st week of life: • In V_1 – V_2: negative T wave • In V_6: positive T wave

still elevated. Elevated PVR is normal in the first week of life but afterwards it gradually reduces toward normal levels in normal subjects. A negative T wave shows normal maturation of the pulmonary vascular bed.

After the first week of life a positive T wave in V_1–V_2, indicates raised systolic pressure in the right ventricle, and can be a sign of congenital heart disease causing right ventricular pressure load.

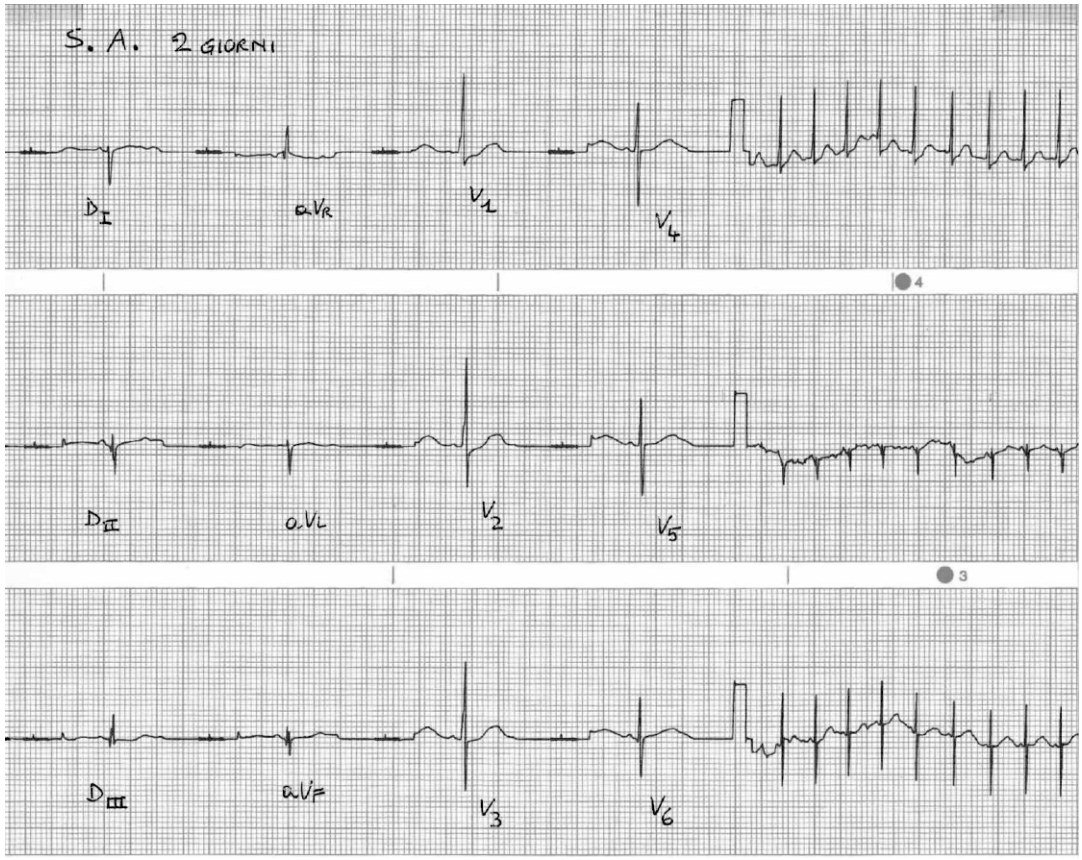

Fig. 1.1 Electrocardiogram recorded of a 2-day-old newborn

The ECG in Fig. 1.1 shows the characteristics of the "neonatal pattern". Looking at the morphology of the V_1 and V_6 precordial leads, one can see the prevalence of the right ventricle in ventricular depolarization (in V_1: R wave > S wave, therefore R/S > 1; in V_6: S wave is 8 mm deep, and R/S = 1). In the repolarizing electrical activity one can see a positive T wave in V_1–V_2 and V_6, fitting the normal pattern for the first week of life.

This patient was two days old and this "neonatal pattern" is congruous with his age, thus this ECG is normal.

The other parameters to be read are within the normal range defined in this manual: sinus rhythm, a PR interval of 100 ms, QRS duration of 50 ms, QRS frontal axis of +180° (strain and right axial deviation, which is normal in the first week of life), QTc interval of 452 ms (longer than the 440 ms normal limit, but not considered pathological in the first few weeks of life).

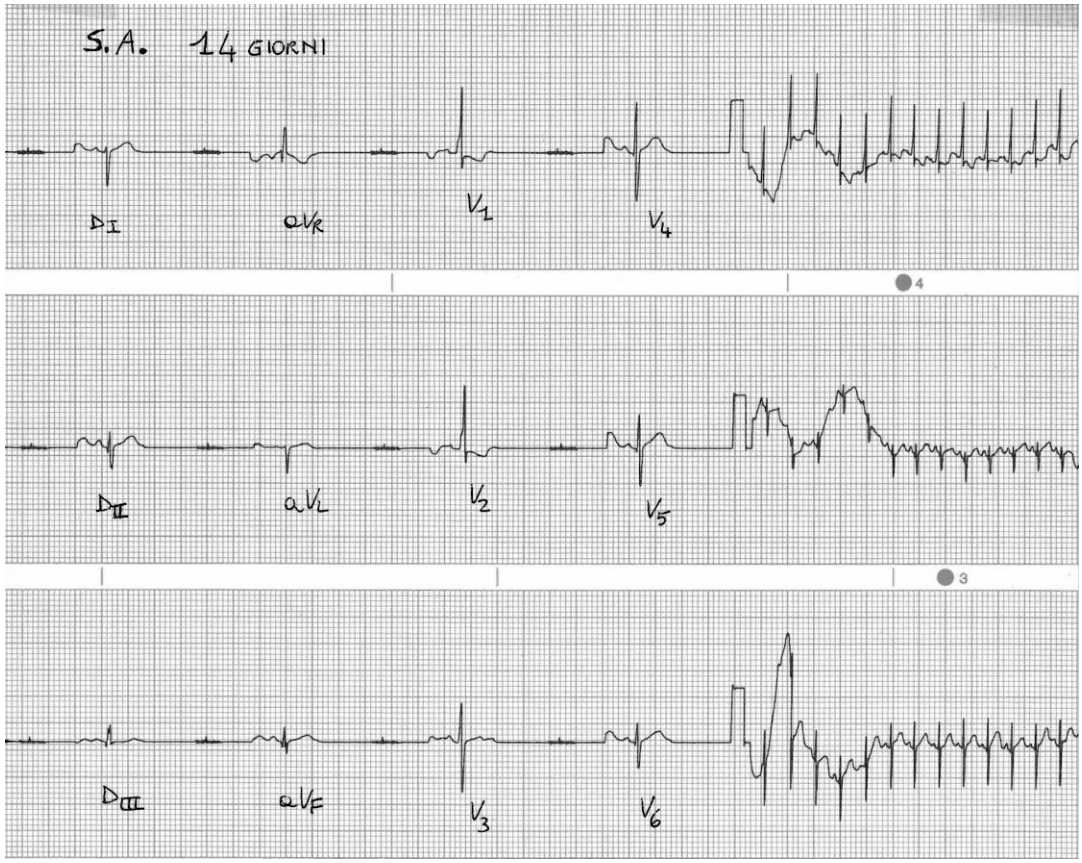

Fig. 1.2 Electrocardiogram of the same newborn as in Fig. 1.1, recorded at 14 days

Considering the morphology of the V_1 and V_6 precordial leads, the trace in Fig. 1.2 maintains the characteristics of the "neonatal pattern" in terms of ventricular depolarization. It also shows the repolarizing electrical activity of the ventricles is evolving normally since the T wave changes from positive to negative in V_1–V_2 leads, as is normal after the first week of life. This signifies normal maturation of the pulmonary vascular bed, with gradual reduction of PVR. The QTc value of 433 ms has also normalized.

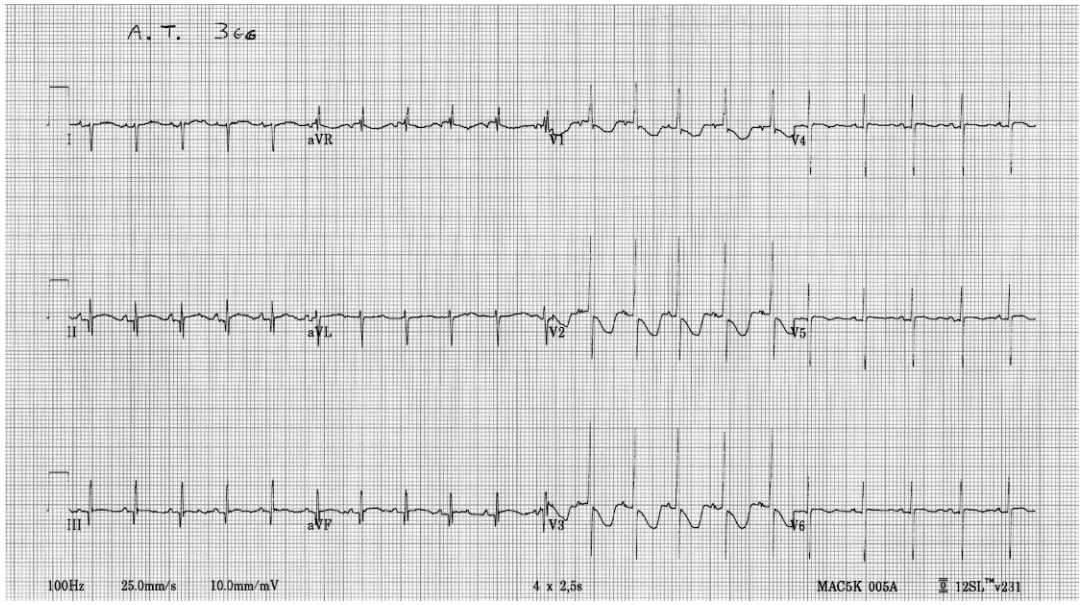

Fig. 1.3 Electrocardiogram recorded of a 3-day-old newborn

Characteristics of the "neonatal pattern" can be recognized in Fig. 1.3. In V_1, the R wave > the S wave therefore R/S > 1 and in V_6 the S wave is deep and has a voltage at the upper limits of the norm (1 mV) such that R/S < 1. The T wave of ventricular repolarization is negative in V_1, V_2 and V_3 precordial leads while it is flat in V_5 and V_6, which is a normal variant in the first week of life. The QRS frontal axis is right deviated (+140°) which is also normal in the first week of life. This electrocardiogram is normal since it is congruous with the age of the patient.

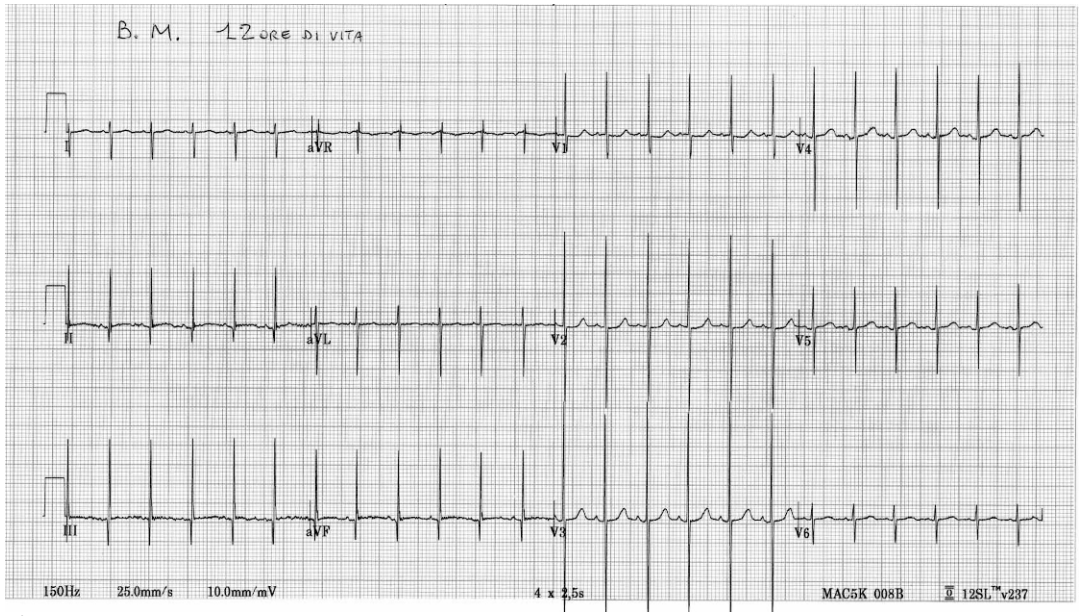

Fig. 1.4 Electrocardiogram recorded of a 12-hour-old newborn

In Fig. 1.4, with reference to ventricular depolarization (the V_1 and V_6 precordial leads), it is clear that the right ventricle electrical activity prevails, which is normal in the first month of life. The T wave of ventricular repolarization is positive in V_1–V_2, which is within the norm for the first week of life. The T wave is positive in V_5 and V_6, which is also normal. The QRS frontal axis is right deviated at +110°, which is within the norm through the first year of life. This ECG is normal because of the concordance between the "neonatal pattern" and the age of the patient, both in terms of depolarization and ventricular repolarization.

Fig. 1.5 Electrocardiogram recorded of a 24-hour-old newborn

In Fig. 1.5, the electrical prevalence of the right ventricle fits the "neonatal pattern" (in V_1 the R/S ratio > 1; in V_6 the R/S ratio = 1). In terms of ventricular repolarization, the T wave is diphasic in V_1, V_2 and V_3 (considered normal in the first week of life) and positive in V_5–V_6. All these elements indicate this trace is normal. The QRS frontal axis is right deviated at +120°, which is normal in relation to the patient's age.

Fig. 1.6 Electrocardiogram recorded of a 3-day-old newborn

Looking at the V_1 and V_6 precordial leads in Fig. 1.6, one sees the electrical prevalence of the right ventricle, which fits the "neonatal pattern" and is congruous with the age of this 3-day-old patient. The morphology of ventricular repolarization already shows the normal reduction of the PVR since the T wave is negative in the V_1–V_2–V_3 precordial leads. The QRS frontal axis shows strain and right deviation (+180°), which is within the variations of the norm in the first week of life.

Fig. 1.7 Electrocardiogram recorded of a 20-day-old newborn

Figure 1.7 shows that, with regard to ventricular depolarization, the electrical forces in the right ventricle dominate both in V_1, in that R/S > 1, and in V_6 in that R/S < 1. In ventricular repolarization, the T wave is negative in V_1, V_2 and V_3 precordial leads and positive in V_5, and V_6. The QRS frontal axis has kept a strong right deviation at +170°, which is still to be considered within normal limits in the first month of life. All these elements fit the "neonatal pattern". These elements are appropriate for the age of the patient and this trace is interpreted as normal.

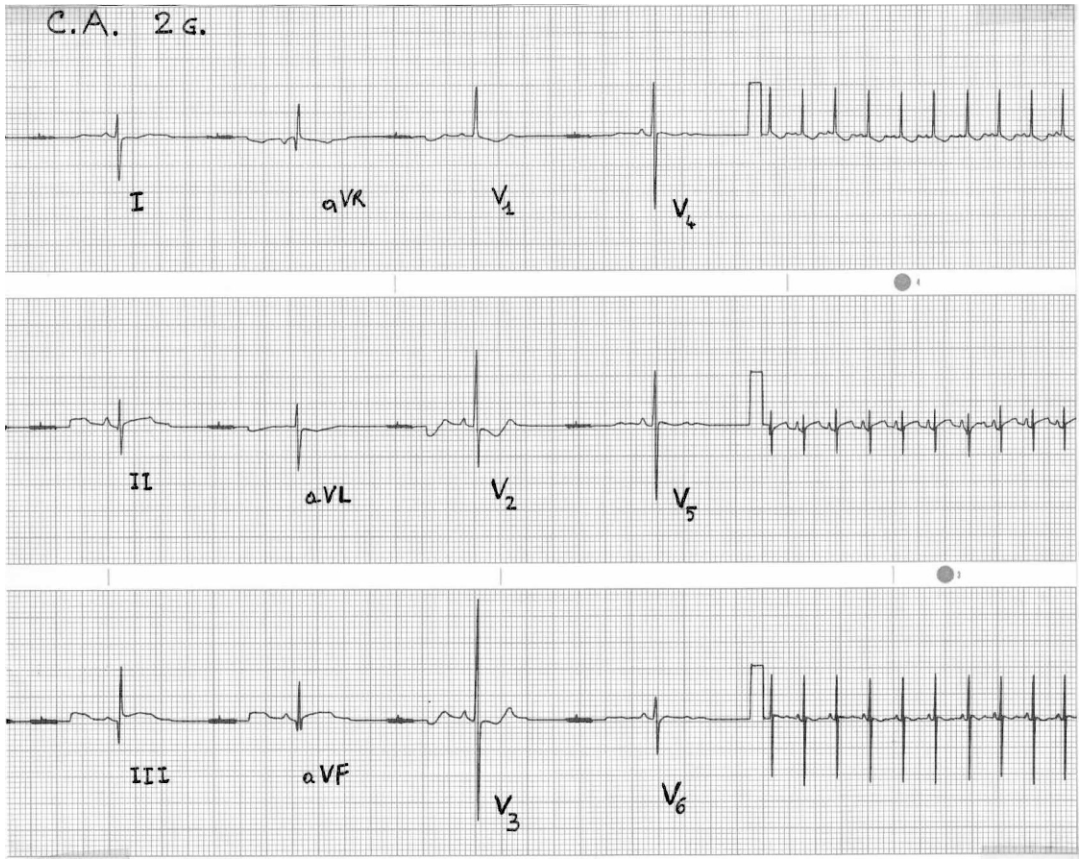

Fig. 1.8 Electrocardiogram recorded of a 2-day-old newborn

The ECG in Fig. 1.8 shows a variant of the "neonatal pattern" since the R wave is exclusive in V_1 (the S wave of electrical activity in the left ventricle is absent). For this to be normal, the voltage of the R wave must be less than 13 mm (1.3 mV) in the first week of life and less than 10 mm (1 mV) afterwards. In this case, the voltage of the exclusive R wave is 1 mV, so it is normal.

One can see that the electrical forces of the right ventricle are prevalent in V_6 such that R/S < 1. This is prescribed by the "neonatal pattern".

With reference to ventricular repolarization, the T wave is diphasic in V_1, V_2 and V_3, and flat or tendentially positive in V_5–V_6, which is a variant of the norm for the first week of life. The QRS frontal axis is right deviated at +150°, which is normal in the first week of life.

Fig. 1.9 Electrocardiogram recorded of a 4-day-old newborn

In the V_1 precordial lead in Fig. 1.9, a dominant depolarizing R wave of the right ventricle is visible such that R/S > 1. In V_6, one can see a depolarizing S wave of the right ventricle, which is dominant over the R wave of left ventricular depolarization such that R/S < 1. This confirms a morphology of electrical dominance of the right ventricle. This fits the "neonatal pattern" and is in concordance with the age of the patient, thus the ECG is normal. The ventricular repolarization is also normal since the T wave is negative in V_1–V_2–V_3 and positive in V_5–V_6 precordial leads.

The QRS frontal axis is right deviated at +160°, which is normal in the first week of life.

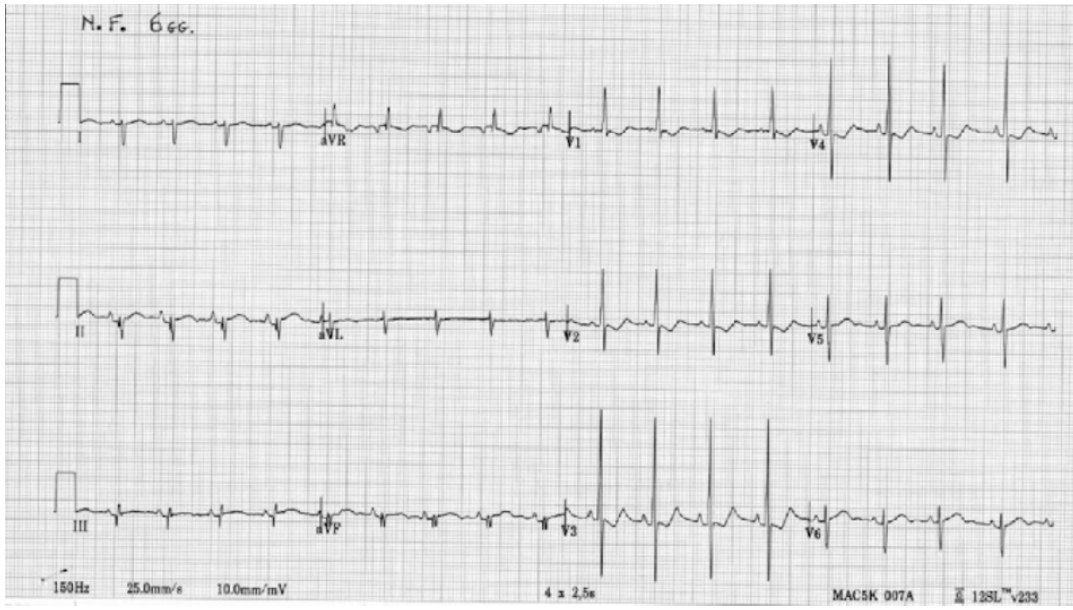

Fig. 1.10 Electrocardiogram recorded of a 6-day-old newborn

In examining the morphology of ventricular depolarization in the precordial leads in Fig. 1.10, one can see the characteristics of the "neonatal pattern" of the right ventricular prevalence in electrical activity (in V_1, R/S > 1; in V_6, R/S < 1). As far as ventricular repolarization is concerned, the T wave is diphasic in V_1, V_2 and V_3 (normal in the first week of life) and positive in V_5–V_6. These elements mean this ECG is normal, since they are in concordance with this 6-day-old patient's age.

The QRS frontal axis is extremely right deviated at +210°, which is still within normal limits for the first week of life.

Fig. 1.11 Electrocardiogram recorded of a 5-day-old newborn

With regard to ventricular depolarization in the V_1 and V_6 precordial leads, one can see the "neonatal pattern" of right ventricular electrical dominance (Fig. 1.11), which is congruous with the age of the patient. In V_1, a 5 mm exclusive R wave is present, which is within the 1.3 mV normal limit for the first week of life. In V_6, the S wave of right ventricular depolarization prevails such that $R/S < 1$.

In terms of the morphology of ventricular repolarization, a negative T wave is observed in V_1, V_2 and V_3 as is normal. In V_6, the T wave is negative, which is a variant of the norm for the first week of life.

The QRS frontal axis is extremely right deviated at +210°, which is within the normal limits for the first week of life. This ECG is, therefore, normal in relation to the age of the patient.

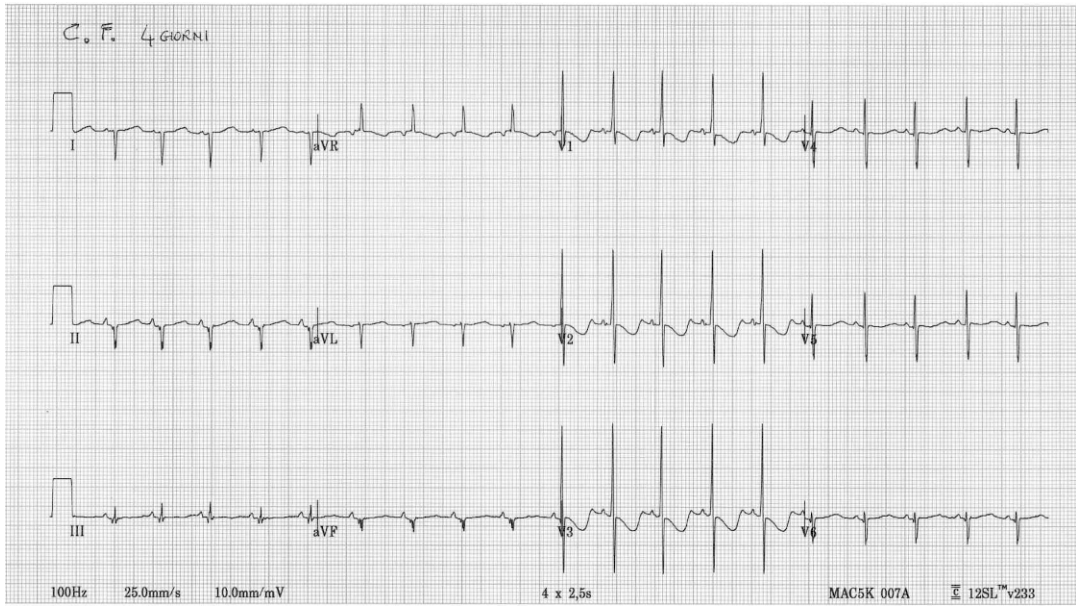

Fig. 1.12 Electrocardiogram recorded of a 4-day-old newborn

When considering ventricular depolarization, the "neonatal pattern" can be seen in the precordial leads V_1 and V_6 (Fig. 1.12), which is congruous with the age of the patient. The electrical force of the right ventricle prevails in V_1, with a dominant R wave such that $R/S > 1$. In V_6, the electrical force of the right ventricle still prevails, with a dominant S wave such that $R/S < 1$.

The morphology of ventricular repolarization fits the normal pattern since the T wave is negative in V_1, V_2 and V_3, and positive in V_6. The QRS frontal axis is right hyperdeviated at +200°, which is considered within the norm for the first week of life. This ECG is normal given the age of the patient.

Fig. 1.13 Electrocardiogram recorded of a 6-day-old newborn

The "neonatal pattern" can also be recognized in Fig. 1.13, and is congruous with the age of the patient. In V_1, the electrical force of the right ventricle prevails, with a dominant R wave such that $R/S > 1$. In V_6, the electrical force of the right ventricle still prevails, with a dominant S wave such that $R/S < 1$.

With regard to ventricular repolarization, the T wave is still positive in V_1, V_2 and V_3, which is a variant of the norm in the first week of life. In V_6, the T wave is positive.

The QRS frontal axis is right hyperdeviated at +210°, which is normal for the first week of life. This ECG is normal considering the age of the patient.

Fig. 1.14 Electrocardiogram recorded of a 4-day-old newborn

The "neonatal pattern" is well represented by the electrical dominance of the right ventricle in Fig. 1.14. In V_1, the R wave of the right ventricular depolarization prevails such that R/S > 1. In V_6, the S wave of right ventricular depolarization still prevails such that R/S < 1.

The morphology of ventricular repolarization is normal with a negative T wave in V_1, V_2 and V_3, and a positive one in V_6. The right hyperdeviation of the QRS frontal axis (+210°) is within the norm for the first week of life. Put together, these elements define this ECG as normal, given the age of the patient.

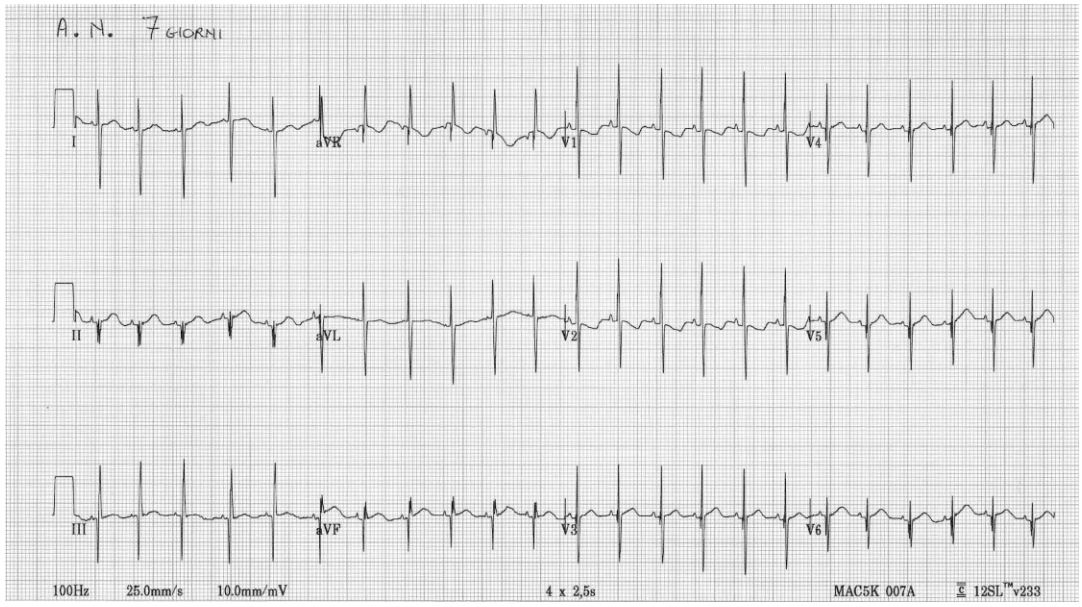

Fig. 1.15 Electrocardiogram recorded of a 7-day-old newborn

The electrical dominance of the right ventricle in the V_1 and V_6 precordial leads in Fig. 1.15 fits the "neonatal pattern". There are narrow and deep Q waves in the II, III and aV_F extremity leads. This aspect is a normal variation since the voltage is under 1 mV.

Ventricular repolarization is normal since the T wave is negative in V_1–V_2 and positive in V_6. The QRS frontal axis is right hyperdeviated at +200°, which is a variant of the norm in the first week of life. Therefore, this ECG is normal considering the age of the patient.

1.2 The Infant Pattern

Within the first few hours after birth hemodynamic changes begin, which form the basis of the morphological changes in the ECG.

The main change deals with PVR. A process of remodeling or maturation of the pulmonary vascular bed begins at birth. Over several months, the changes, which are at first dynamic, and later, anatomical, bring about the hemodynamic adult state.

At birth, a reduction in PVR begins because of:

- Dilation of the pulmonary muscular arterioles, mainly governed by a rise in partial oxygen pressure that comes with the onset of breathing and other vasodilating factors (prostacyclin I2, nitric oxide). Furthermore, vasoconstrictor effects of vasoactive mediators (hypoxia, acidosis, endothelin, thromboxane) become less effective.
- Recruitment of peripheral arteries previously closed in the fetal life, due to the draining of liquid that filled the alveoli (during gestation) and compressed the pulmonary vascular bed.
- Gradual decrease of medial muscle layer of the pulmonary arteries and arterioles by remodeling (lengthening and compression) of smooth muscle cells of the tunica media, with the consequent widening of the internal diameter of the vessel lumen and thinning of the tunica media in most of the distal muscular pulmonary arteries.
- Widening of the diameter of the small pulmonary arteries following the increase in pulmonary blood flow after birth.

The increase of the pulmonary vascular bed, and the gradual fall that results in PVR, bring about a gradual reduction in right ventricular systolic pressure. Consequently, right ventricular mass and right ventricular electrical forces gradually decrease.

After birth, the left ventricle follows the opposite course. It ceases to pump against the low resistance of the blood vessels in the placenta, and begins pumping against the high resistance of the peripheral blood vessels. This brings about a rise in left ventricular systolic pressure and a gradual rise in left ventricular mass, which in turn raises the electrical force of the left ventricle.

Therefore, from birth through the first month of life, the right ventricle loses mass and electrical force through the gradual reduction of PVR. Meanwhile, the left ventricle gradually gains mass and electrical force by pumping against high peripheral vascular resistance. This dynamic continues and builds on itself throughout the first year of life. With the normalization of PVR and its systolic pressure, the right ventricle grows more slowly than the left. This is reflected in the relationship between the electrical forces of the two ventricles.

This gradual evolution, which reflects hemodynamic changes, balances the electrical forces of the left and right ventricles. This change marks the transfer from the "neonatal pattern" to what is defined as the "infant pattern". The "infant pattern" is characterized by balanced ventricular electrical forces. This is the normal ECG pattern found after the first month of life up to two years. Normal variants include the presence of this pattern already at birth all the way through to the age of 3.

Like in the "neonatal pattern", to define "the infant pattern" one must consider the morphology of the QRS complex and that of the T wave in the precordial leads. As with the neonatal pattern, it is sufficient to focus on V_1 and V_6. The positioning of the leads and the electrical activity indicated by the R and S waves are the same as described for the neonatal pattern.

After the first month of life the electrical forces of the ventricles are balanced, therefore, the infant ECG pattern shows equal electrical weight of the two ventricles. In the V_1 lead, the R wave will still be dominant over the S wave such that $R/S > 1$ (the R wave in V_1 represents the depolarizing electrical activity of the right ventricle), although to be considered normal, its voltage should be less than 20 mm (2 mV). In the V_6 precordial lead, the R wave will be dominant over the S wave

Table 1.3 Infant pattern. Ventricular depolarization. Balanced electrical forces in the ventricles are normal in infant pattern

QRS – Infant pattern	
In V_1: dominant R wave such that R/S > 1	R wave < 20 mm
In V_6: dominant R wave such that R/S > 1	R wave < 25 mm
	S wave < 10 mm
In V_1: if R wave is exclusive	R < 10 mm; never occurs after 1st year of life
In II–III–aV_F–V_6: Q wave up to 10 mm in depth	

Table 1.4 Infant pattern. Ventricular repolarization

T wave – Infant pattern	
In V_1–V_2–V_3: negative	after the 1st week of life up to age 8–10
In V_6: positive	after the 1st week of life

such that R/S > 1 (the R wave in V_6 represents the depolarizing electrical activity of the left ventricle), although to be considered normal, its voltage should be less than 25 mm (2.5 mV) and that of the S wave should be less than 10 mm (1 mV). In V_1, the R wave may be exclusive but to remain within the norm, its voltage should be less than 10 mm (1 mV) and never present after the first year of life (see Table 1.3).

A unique characteristic of the "infant pattern" is the potential for a narrow Q wave, up to 10 mm (1 mV) deep to appear in the II, III and aV_F extremity leads, as well as in the V_6 precordial lead. When this occurs, it is within the variations of the norm.

The "infant pattern" of the repolarizing electrical activity of the ventricles, has a negative T wave in V_1–V_2–V_3, as late as the age of 8–10 years and positive T wave in V_6 (see Table 1.4).

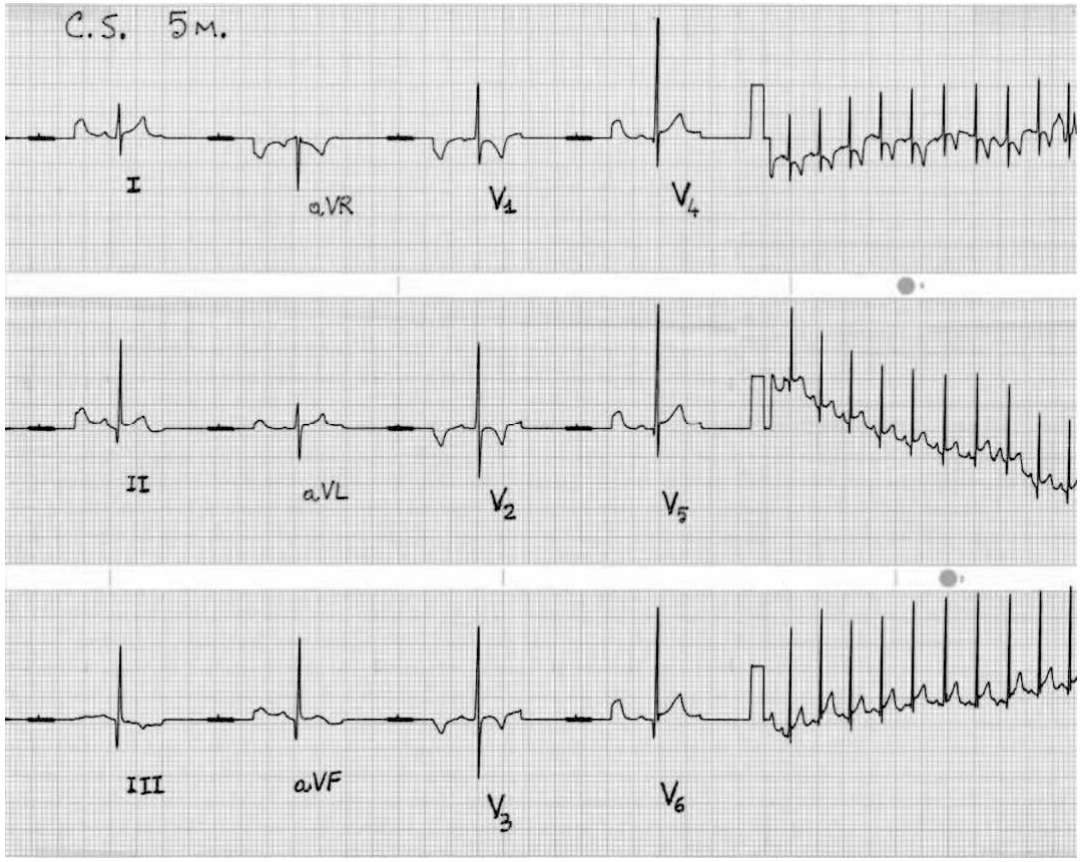

Fig. 1.16 Electrocardiogram recorded of a 5-month-old infant

This trace (Fig. 1.16) shows the characteristics of the "infant pattern". The morphology of the V_1 and V_6 precordial leads shows balanced electrical ventricular forces in ventricular depolarization (in V_1 the R wave is dominant such that $R/S > 1$; the expression of the right ventricular electrical forces is still strong. In V_6, the dominant R wave, the expression of the left ventricular electrical forces, is increasing). In ventricular repolarization, the T wave is negative in V_1, V_2 and V_3, and positive in V_5 and V_6. This is within the norm after the first week of life.

This patient is 5 months old and this "infant ECG pattern" is congruent with his age, so the trace is normal. The other parameters of interpretation are in line with the normal range defined in this guide: sinus rhythm, a PR interval of 120 ms, a QRS duration of 60 ms, a QRS frontal axis of +70°, a QTc interval of 398 ms.

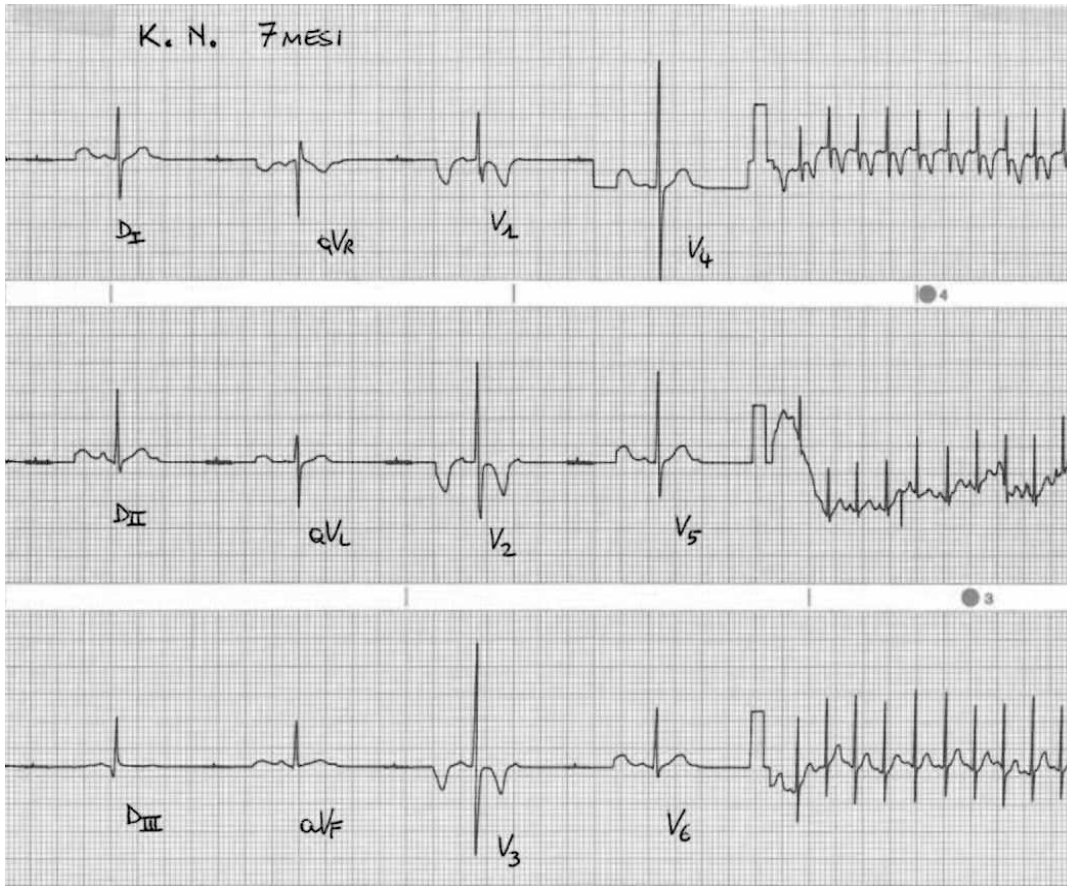

Fig. 1.17 Electrocardiogram recorded of a 7-month-old infant

In Fig. 1.17, for ventricular depolarization, one can see balanced ventricular electrical forces in the V_1 and V_6 precordial leads. In terms of ventricular repolarization, the T wave is negative in V_1, V_2 and V_3 and positive in V_5 and V_6. These qualities define the "infant pattern", which is appropriate for the age of this patient, thus this trace is normal.

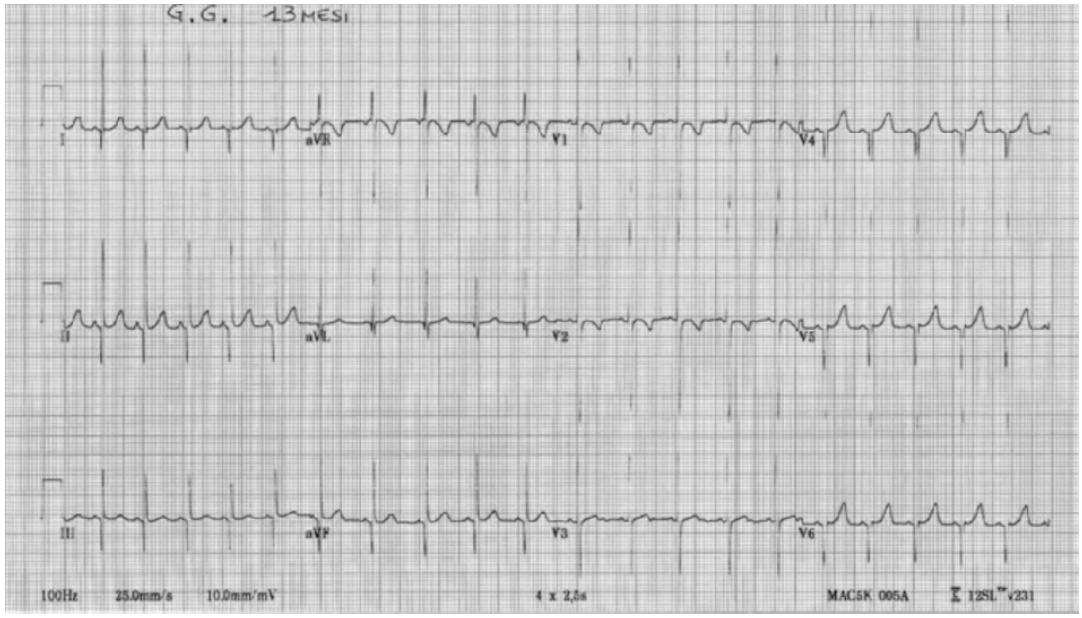

Fig. 1.18 Electrocardiogram recorded of a 13-month-old infant

In Fig. 1.18, for V_1, both the right ventricular depolarizing R wave and the left ventricular depolarizing S wave have almost equally high voltage, which is still within normal limits (2 mV). In V_6, the electrical activity of the left ventricle is dominant, with the S wave practically absent. All in all, one can say the electrical forces of the ventricles are balanced in this trace (Fig. 1.18), so it fits the "infant pattern". The "infant pattern" is characterized here by a deep Q wave in II, III, aV_F and V_6 leads, which does not surpass 10 mm (1 mV) in voltage and, thus is considered normal. In ventricular repolarization, the T wave is negative in V_1–V_2 and positive in V_5–V_6, which is normal. This ECG is appropriate for the age of the patient and is considered normal.

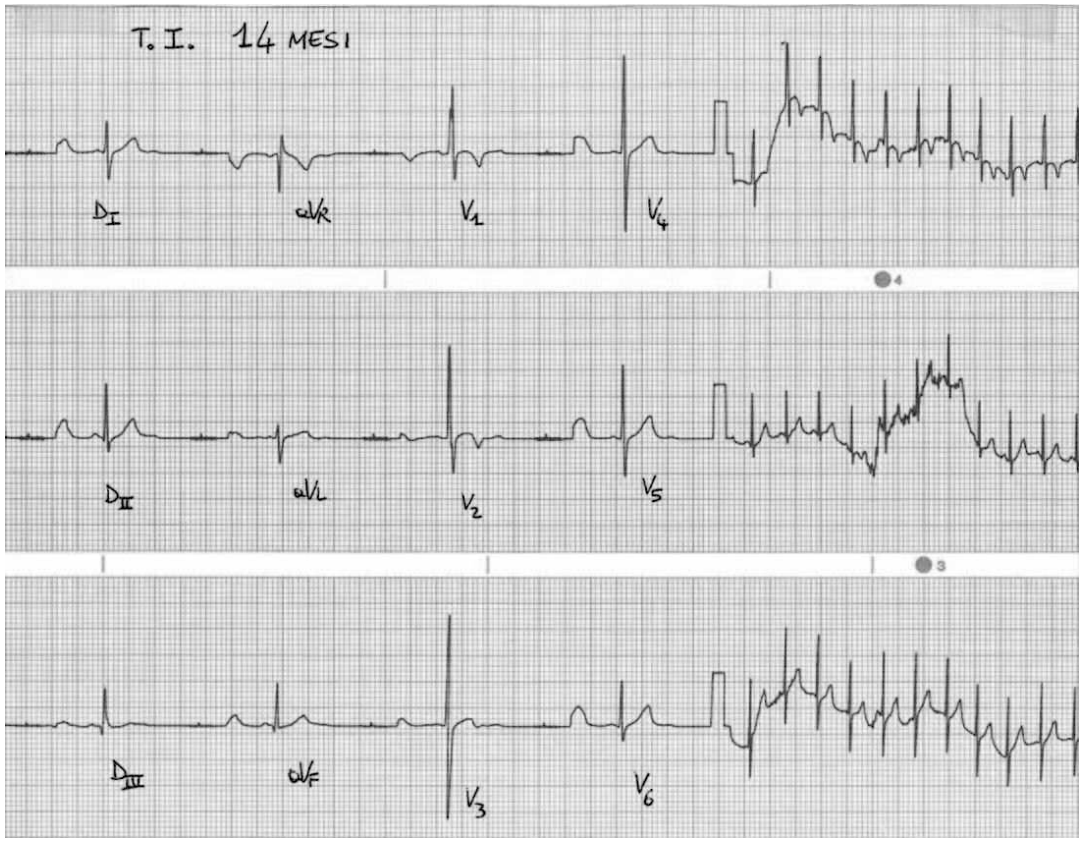

Fig. 1.19 Electrocardiogram recorded of a 14-month-old infant

In Fig. 1.19, with V_1, the R wave (electrical forces of the right ventricle) is dominant over the S wave with a slight slurring in the rise, an expression of brief delay in right intraventricular conduction, which should be considered a variant of the norm. In V_6, the R wave (electrical forces of the left ventricle) dominates over the S wave such that R/S > 1. These qualities indicate balanced electrical forces of the right and left ventricles, that is, an "infant pattern", congruent with the age of the patient. Ventricular repolarization is as it should be (T wave negative in V_1–V_2 and positive in V_5–V_6) and, at +80°, the QRS frontal axis is within the norm. This ECG is read as normal.

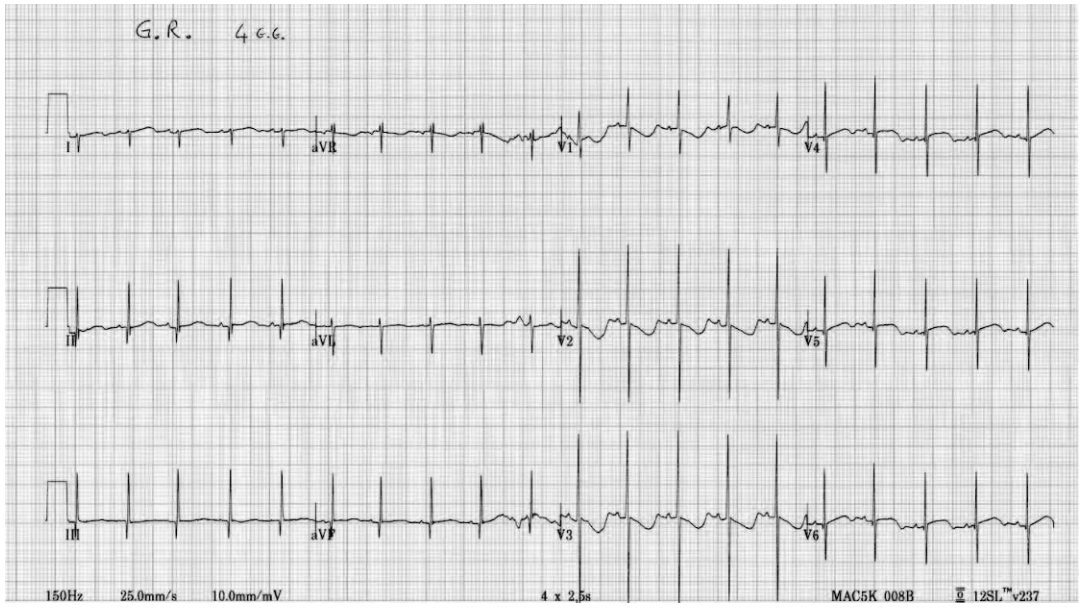

Fig. 1.20 Electrocardiogram recorded of a 4-day-old newborn

In Fig. 1.20, for V_1, the R wave (electrical forces of the right ventricle) is dominant over the S wave, and in V_6, the R wave (expression of electrical forces in the left ventricle) is dominant over the S wave, producing a situation with balanced ventricular electrical forces. This "infant pattern" can already be present at birth, so this electrocardiogram of a 4-day-old newborn should be considered normal. The normal morphology of ventricular repolarization (T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6) also confirms this ECG is normal.

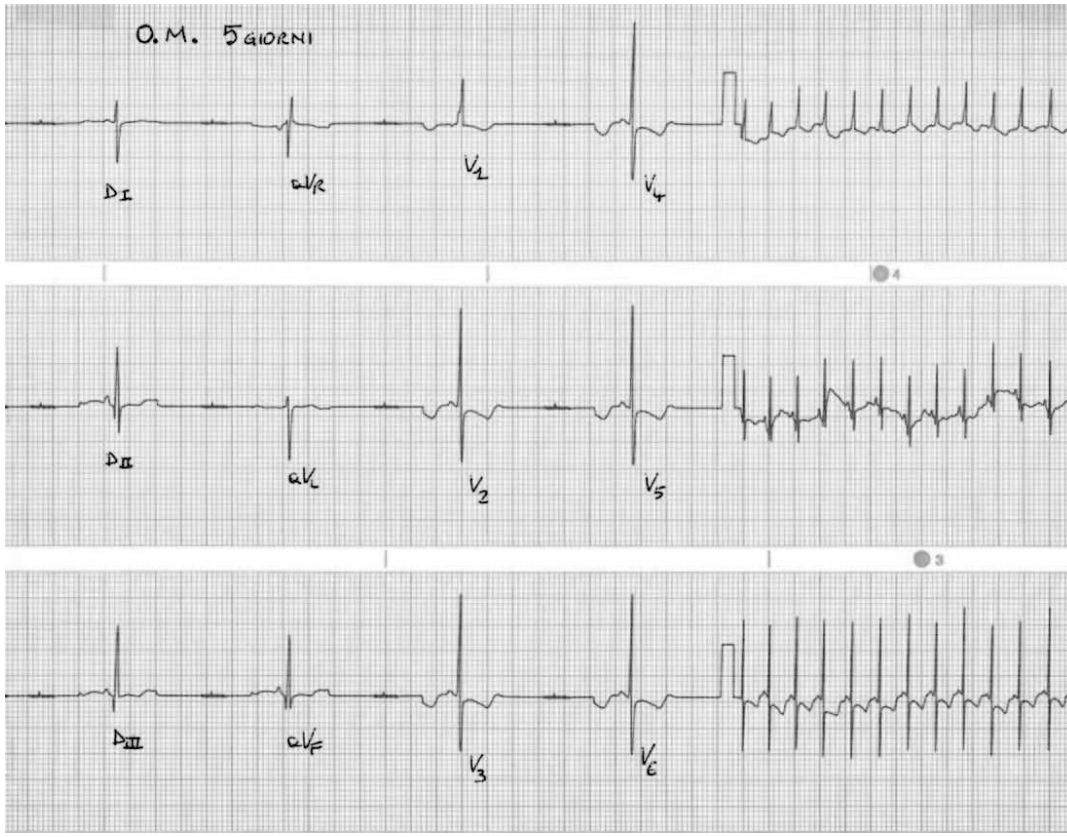

Fig. 1.21 Electrocardiogram recorded of a 5-day-old newborn

Here, a situation analogous to the one in Fig. 1.20 is shown. In this trace (Fig. 1.21), the electrical forces of the ventricles are balanced, thus this is an "infant pattern", which is considered normal even in the first week of life. The right ventricle's electrical dominance in V_1 is shown here by the exclusive 9 mm (0.9 mV) voltage R wave, which is within the 13 mm (1.3 mV) limit recommended for the first week of life. In V_6, the electrical dominance of the left ventricle is shown by the typical $R/S > 1$ relationship.

The morphology of ventricular repolarization is to be considered normal due to the negative T wave in V_1, V_2 and V_3. A negative T wave in V_5 and V_6 in the first week of life is not a sign of a pathological condition.

The QRS frontal axis is right deviated at +120°, which is normal in newborns.

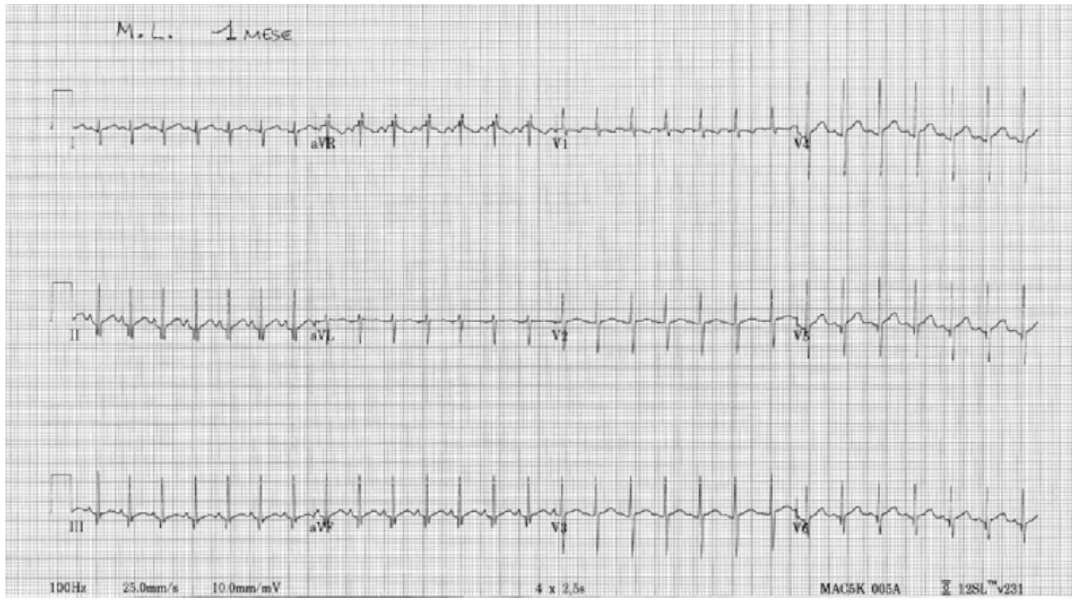

Fig. 1.22 Electrocardiogram recorded of a 27-day-old newborn

In Fig. 1.22, with regard to ventricular depolarization, a situation of balanced electrical forces in the ventricles can be seen; there is right ventricular dominance in V_1 and left ventricular dominance in V_6. Ventricular repolarization is normal since the T wave is negative in V_1 and positive in V_5 and V_6. This "infant pattern" can be present as early as the first few days of life. The QRS frontal axis is modestly right deviated at +100°, which is normal in the first month of life. This ECG is in accordance with the age of this patient, so it is normal.

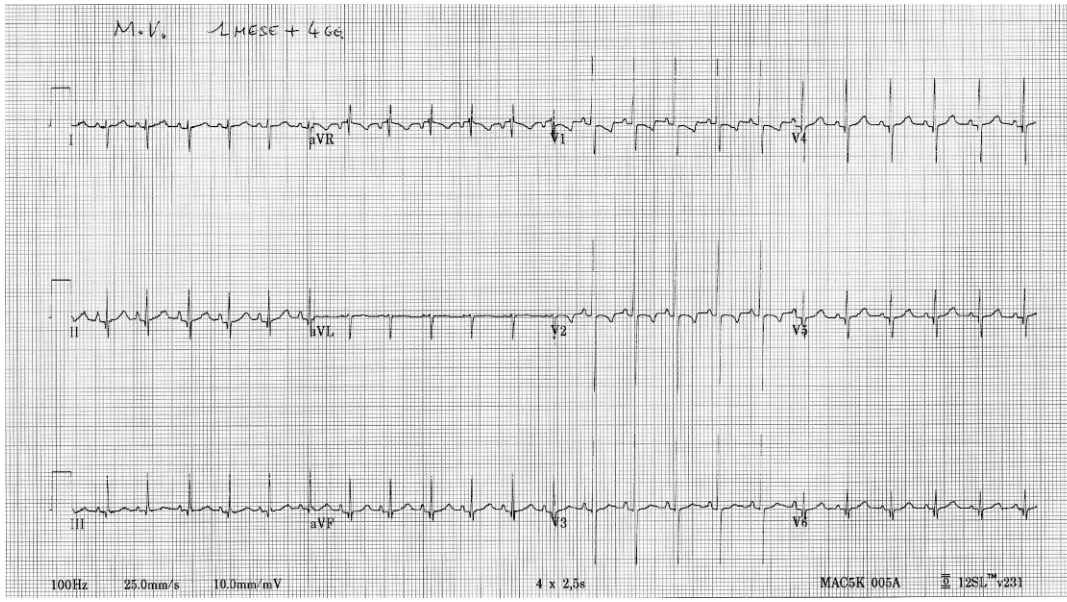

Fig. 1.23 Electrocardiogram recorded of a 35-day-old newborn

The observations made in Fig. 1.22 are also valid in this electrocardiogram sample (Fig. 1.23). The QRS axis here is more strongly right deviated at +120°, but is still within the normal range defined in this manual.

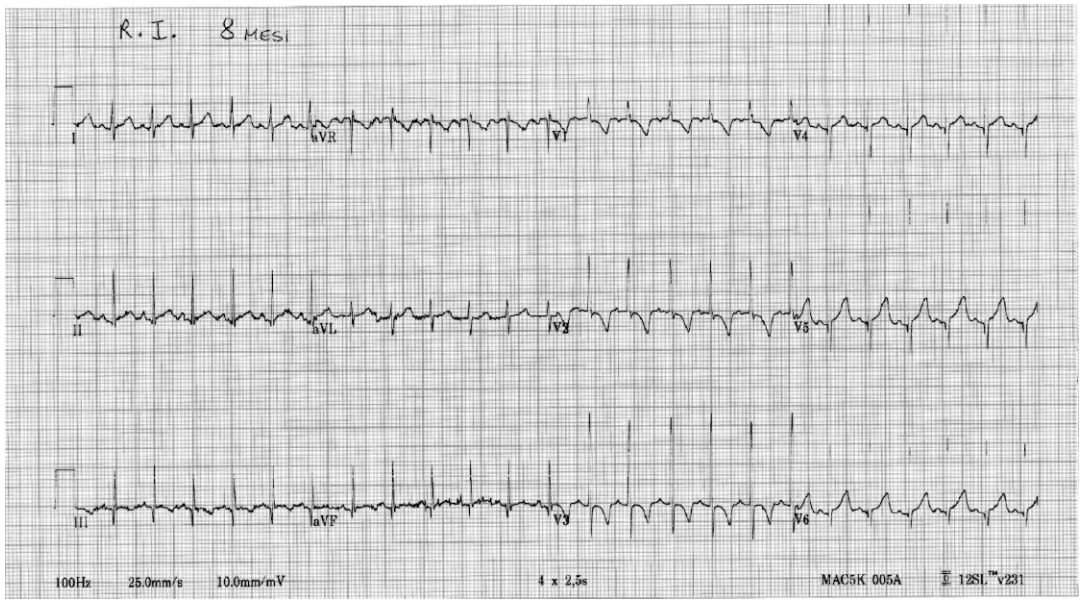

Fig. 1.24 Electrocardiogram recorded of an 8-month-old infant

This electrocardiogram sample (Fig. 1.24) shows a variant of the "infant pattern" of balanced electrical forces in the ventricles. Here, the R wave is exclusive in V_1 (the S wave of depolarizing electrical activity in the left ventricle is not represented). In order to judge this ECG as normal, the voltage of the R wave must be less than 1 mV. This is the case in this sample since the exclusive R wave has a voltage of 0.5 mV.

In V_6, the R wave, which represents left ventricular depolarization, dominates over the small S wave of right ventricular electrical forces. Ventricular repolarization is within the norm since the T wave is negative in V_1, V_2 and V_3, and positive in V_5 and V_6. The QRS frontal axis is normal at +65°.

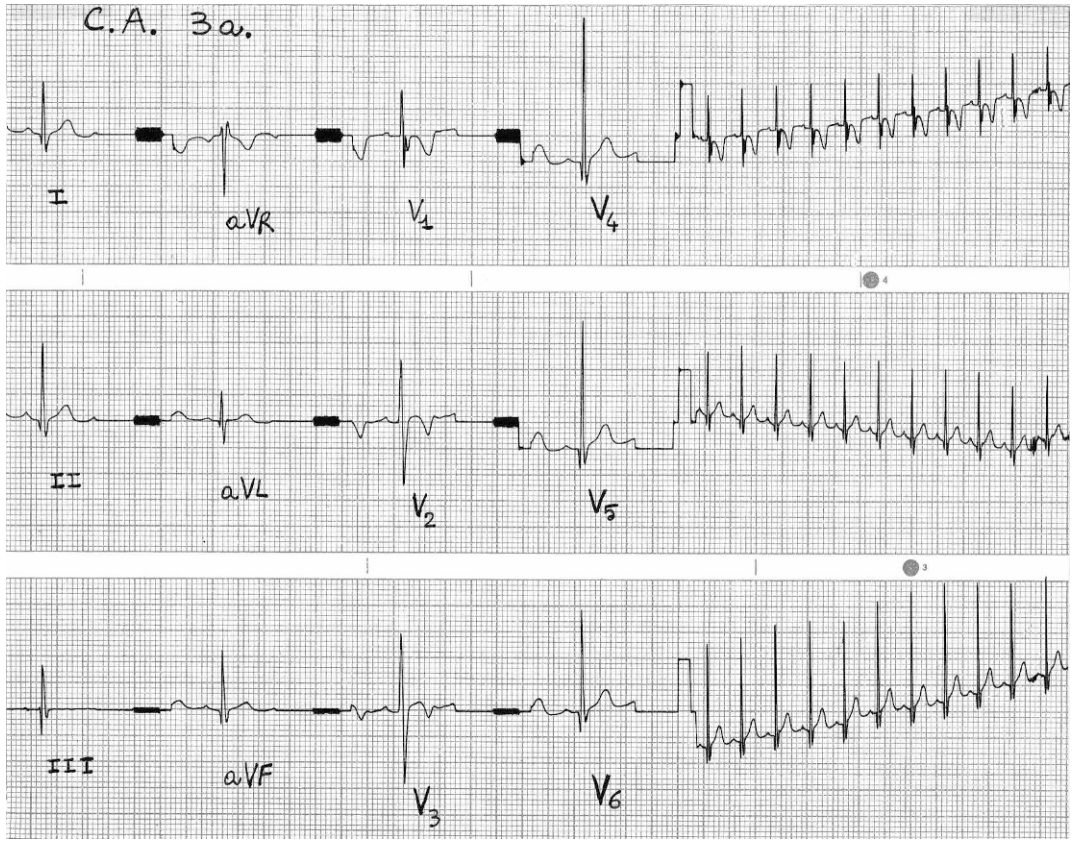

Fig. 1.25 Electrocardiogram recorded of a 3-year-old child

In Fig. 1.25, for V_1, the electrical forces of the right ventricle are prevalent such that R/S > 1. In V_6, however, the electrical forces of the left ventricle are prevalent, with a small S wave and a relationship of R/S > 1. This sets up a picture of balanced electrical forces in the ventricles that fits the "infant pattern", which can last up to the age of 3. Here, the age of the patient is in accordance with this electrocardiogram and thus, this trace should be considered normal.

The morphology of ventricular repolarization (with the T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6), and the QRS axis at +60°, help to define this ECG as normal.

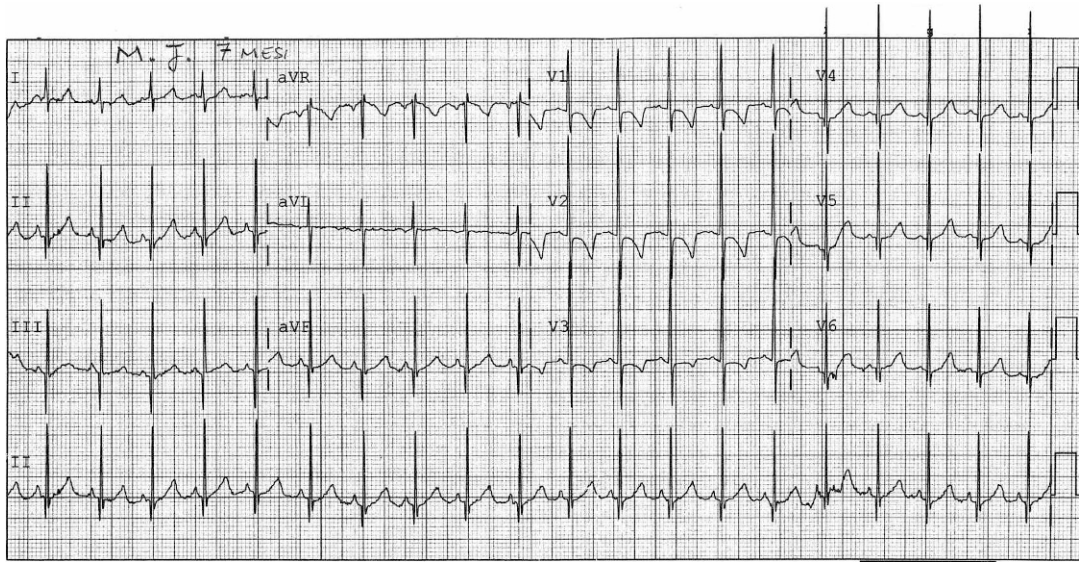

Fig. 1.26 Electrocardiogram recorded of a 7-month-old infant

In Fig. 1.26, with regard to ventricular depolarization, one can see balanced electrical forces in the ventricles. This is represented by electrical dominance of the right ventricle in V_1, in that R/S > 1, and electrical dominance of the left ventricle in V_6. This "infant pattern" is in accordance with the age of the patient and thus, is normal.

The situation with the ventricular repolarization is normal, with the T wave negative in V_1, V_2 and V_3 and positive in V_5 and V_6. At +80°, the QRS frontal axis is also within the normal range. Together these elements define this ECG as normal.

Fig. 1.27 Electrocardiogram recorded of a 3-month-old infant

In Fig. 1.27, with regard to ventricular depolarization, we find balanced ventricular electrical forces in the precordial leads. In V_1, the electrical prevalence of the right ventricle is visible, with the R wave > the S wave such that R/S > 1. In V_6, the electrical forces of the left ventricle prevail with an absent S wave of right ventricular depolarization. The ECG therefore has the characteristics of the "infant pattern" with the variation of a deep Q wave in II, III and aV_F extremity leads with a voltage of 0.7 mV that is within the 1 mV limit defined by the norm.

In the electrical activity of ventricular repolarization, one can see that the T wave is negative in V_1 and positive in V_5 and V_6. The QRS frontal axis is within the norm at +90°. This electrocardiogram fits the "infant pattern", which is congruent with the age of the patient, thus this trace is normal.

Fig. 1.28 Electrocardiogram recorded of a 4-day-old newborn

In the morphology of the precordial leads (Fig. 1.28), one can see the electrical activity of ventricular depolarization has balanced electrical forces in the ventricles. This is in line with the "infant pattern". As a variant, this can be present as early as the first few days of life. In V_1, one can see that the R wave of right ventricular depolarization has a voltage of 2.2 mV, which is at the upper limits of the norm, such that R/S > 1. In V_6, the R wave of left ventricular depolarization dominates, such that R/S > 1. The S wave of right ventricular depolarization has a voltage of 0.3 mV, which is within the 1 mV normal limit.

The electrical activity of ventricular repolarization is within the norm with the T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6. The QRS frontal axis is right deviated at +140°. This is within the norm for the first month of life. This trace can, therefore, be read as normal.

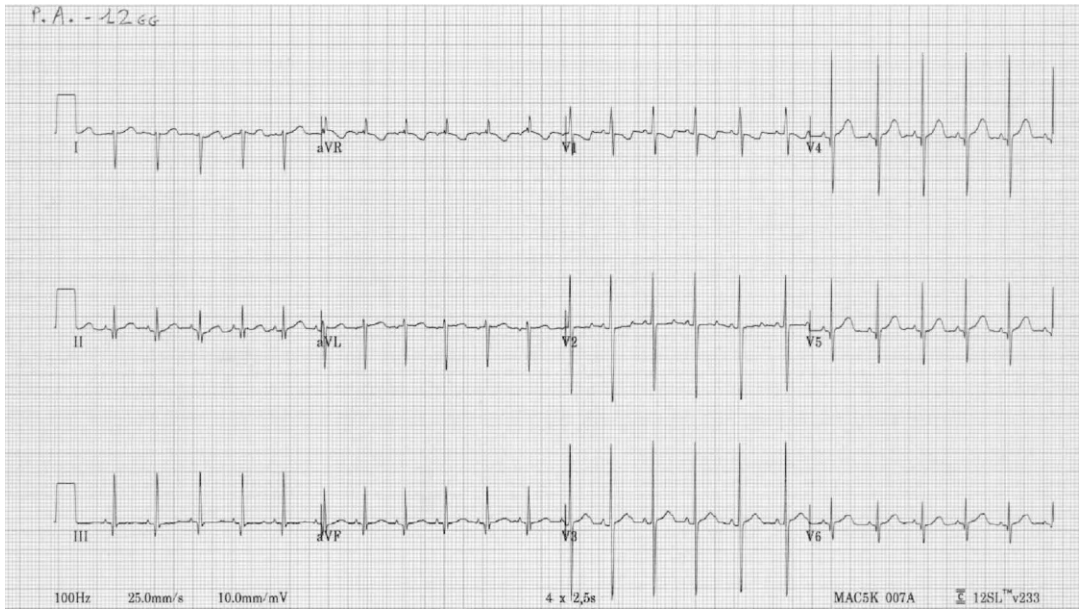

Fig. 1.29 Electrocardiogram recorded of a 12-day-old newborn

Considering the ventricular depolarization in Fig. 1.29, one can see balanced electrical forces in the ventricles, as in the previous ECG. This is represented by electrical dominance of the right ventricle in V_1 and electrical dominance of the left ventricle in V_6. As a variant of the norm, this "infant pattern" can already be present at a few days after birth.

Ventricular repolarization is normal since the T wave is negative in V_1, diphasic in V_2 and positive in V_5 and V_6. The QRS frontal axis is right deviated at +130°, which is normal in the first month of life. This ECG is therefore considered to be normal.

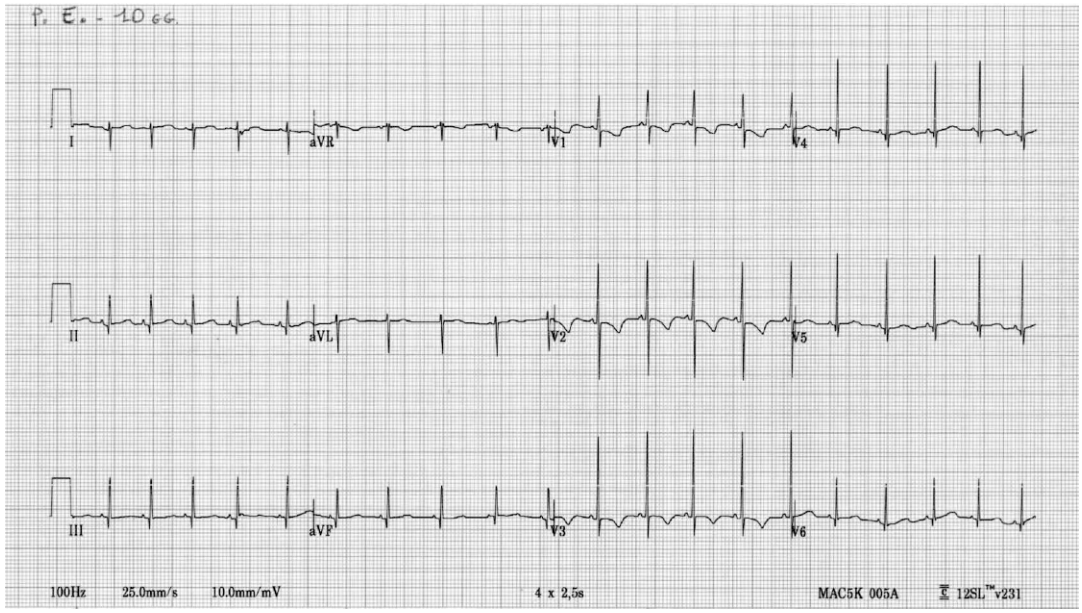

Fig. 1.30 Electrocardiogram recorded of a 10-day-old newborn

In Fig. 1.30, for V_1, the R wave (electrical forces of the right ventricle) dominates over the S wave (electrical forces of the left ventricle). In V_6, the R wave (electrical forces of the left ventricle) dominates. These elements indicate that the right and left ventricular electrical forces are balanced, meaning that this is the "infant pattern". As a variant of the norm, it can already be found in the first month of life. Ventricular repolarization is as it should be since the T wave is negative in V_1, V_2 and V_3; positive in V_5 and V_6. The QRS frontal axis is right deviated at +110°, which is normal for newborns. Together these elements define this trace as normal.

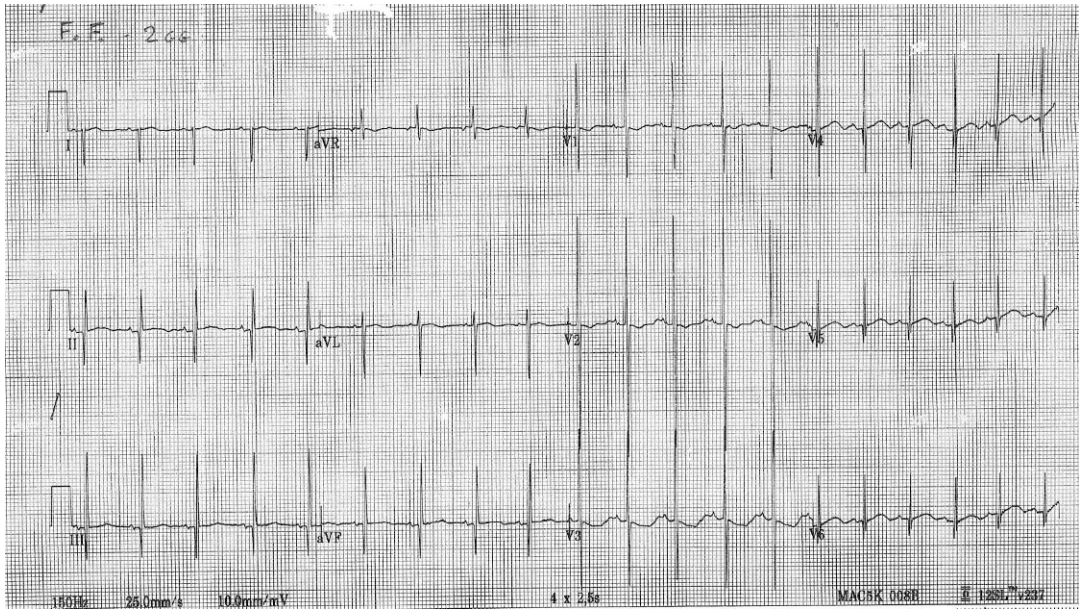

Fig. 1.31 Electrocardiogram recorded of a 2-day-old newborn

Considering the ventricular depolarization in Fig. 1.31, we see balanced electrical ventricular forces in the precordial leads. In V_1, the electrical forces of the right ventricle are prevalent with the R wave > S wave such that R/S > 1. Meanwhile in V_6, the electrical forces of the left ventricle prevail such that R/S > 1. Therefore, this fits the "infant pattern" that can already be present at birth as a variant of the norm. The deep 0.8 mV voltage Q wave in the II, III and aVF leads is within the 1 mV normal limit.

Regarding the electrical activity of ventricular repolarization, the flat/diphasic T wave in V_1–V_2 is also a variant of the norm in the first week of life. The parameters interpretated (sinus rhythm, a PR interval of 100 ms, QRS duration of 50 ms, QRS frontal axis of +130°, QTc interval of 428 ms) are in line with the normal ranges defined in this manual.

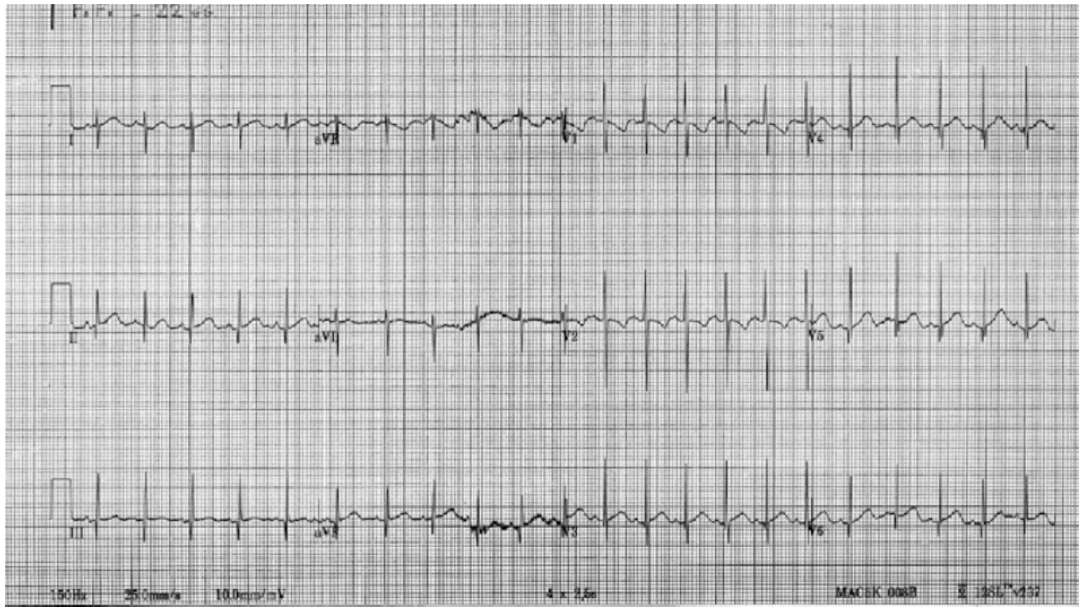

Fig. 1.32 Electrocardiogram recorded of a 22-day-old newborn

This ECG (Fig. 1.32) was recorded 20 days later on the same newborn as in Fig. 1.31. It is an example of the evolving morphology of the ECG pattern in the first few months of life.

With regard to the morphology of the V_1 and V_6 precordial leads, this trace still fits the "infant pattern" characteristics of the electrical activity of ventricular depolarization. In V_1–V_2, the T wave goes from flat to negative, as is normal after the first week of life, signifying the normal maturation of the pulmonary vascular bed, with a gradual fall in PVR.

In accordance with the gradual hemodynamic changes after birth, the reduction of right deviation of the QRS frontal axis (at +110°) indicates a growth of the "electrical mass" of the left ventricle at the expense of the right ventricle.

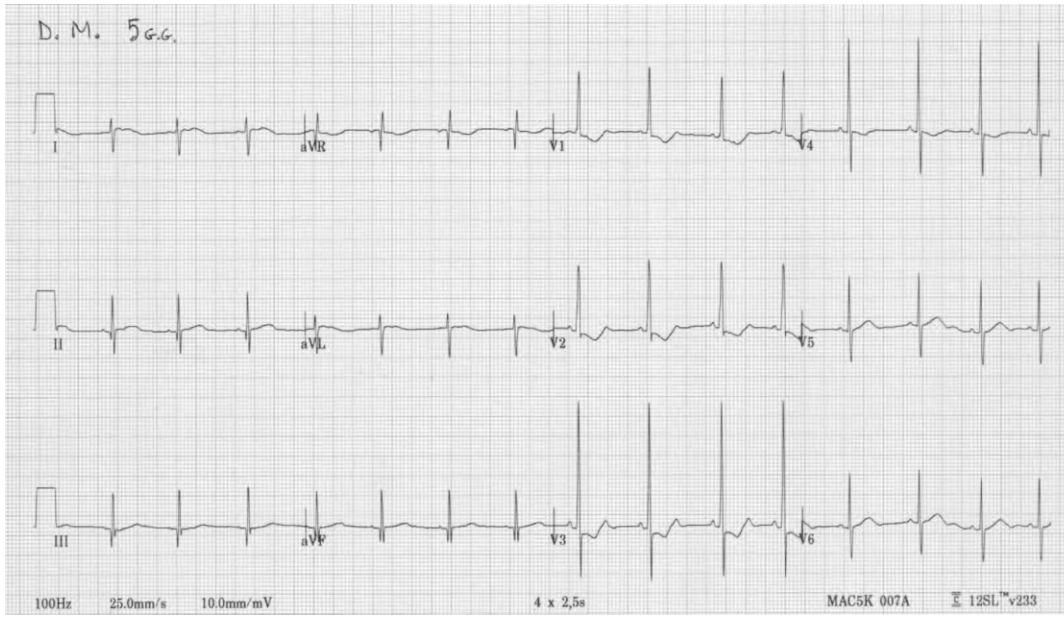

Fig. 1.33 Electrocardiogram recorded of a 5-day-old newborn

Regarding the precordial leads in Fig. 1.33, the electrical forces in the ventricles are balanced, so this fits the "infant pattern", which is normal even for the first week of life. The uniqueness of the electrical dominance of the right ventricle in V_1 is shown here by a high voltage R wave of 15 mm (1.5 mV). It cannot be considered exclusive due to the presence of a miniscule S wave (0.1 mV) of left ventricular depolarization. In V_6, the left ventricle dominates such that R/S > 1. The morphology of ventricular repolarization is within the norm since the T wave is negative in V_1, V_2 and V_3 and positive in V_5 and V_6. The QRS frontal axis is right deviated at +110°, which is normal for a newborn.

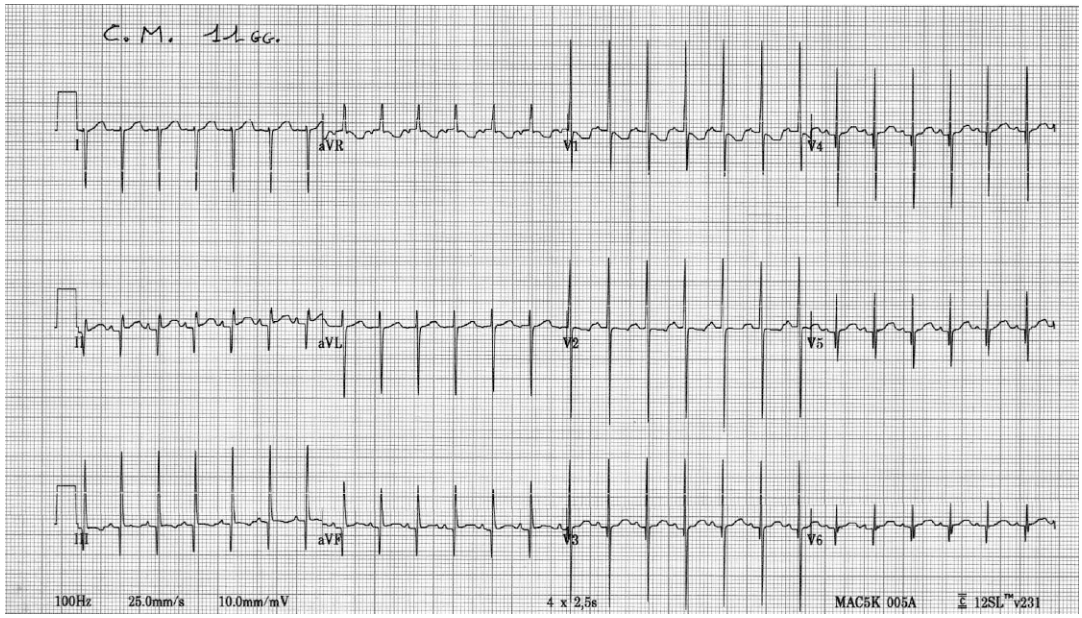

Fig. 1.34 Electrocardiogram recorded of an 11-day-old newborn

Regarding ventricular depolarization, the electrical forces in the ventricles are balanced in this trace (Fig. 1.34), as well. In V_1, the electrical forces of the right ventricle dominate. The R wave of right ventricular depolarization has a voltage of 2.2 mV, at the upper limits of the norm, and an S wave of left ventricular depolarization has a voltage of 1.1mV, such that R/S > 1. The electrical forces of the left ventricle dominate in V_6, such that R/S > 1. The deep Q wave in II, III and aV_F extremity leads has a voltage of 0.7 mV, which is within the normal limit of 1 mV, and therefore is normal.

Ventricular repolarization is normal since the T wave is negative in V_1, diphasic in V_2 and positive in V_5 and V_6. The QRS frontal axis shows right deviation at +160°, which is within the norm for a newborn during the first month of life. As a variant of the norm, this "infant pattern" can already be present in the first few days of life.

Fig. 1.35 Electrocardiogram recorded of a 7-day-old newborn

In Fig. 1.35, when considering the precordial leads, the electrical forces of the ventricles are balanced. V_1 shows right dominance since the R wave of right ventricular depolarization has a voltage at the upper limits of the norm (2 mV) and the S wave of left ventricular depolarization is well represented at 0.9 mV such that R/S > 1. V_6 shows left dominance with an R wave of 0.5 mV, but no S wave of right ventricular depolarization. The deep, 0.7 mV Q wave in II, III and aV_F extremity leads does not surpass the 1 mV normal limit and so is considered normal.

Ventricular repolarization is normal since the T wave is negative in V_1, V_2 and V_3, and positive in V_5 and V_6. The QRS frontal axis shows right deviation at +150°, which is normal for newborns (in the first month of life). As a variant of the norm, the "infant pattern" can already be present in the first few days of life.

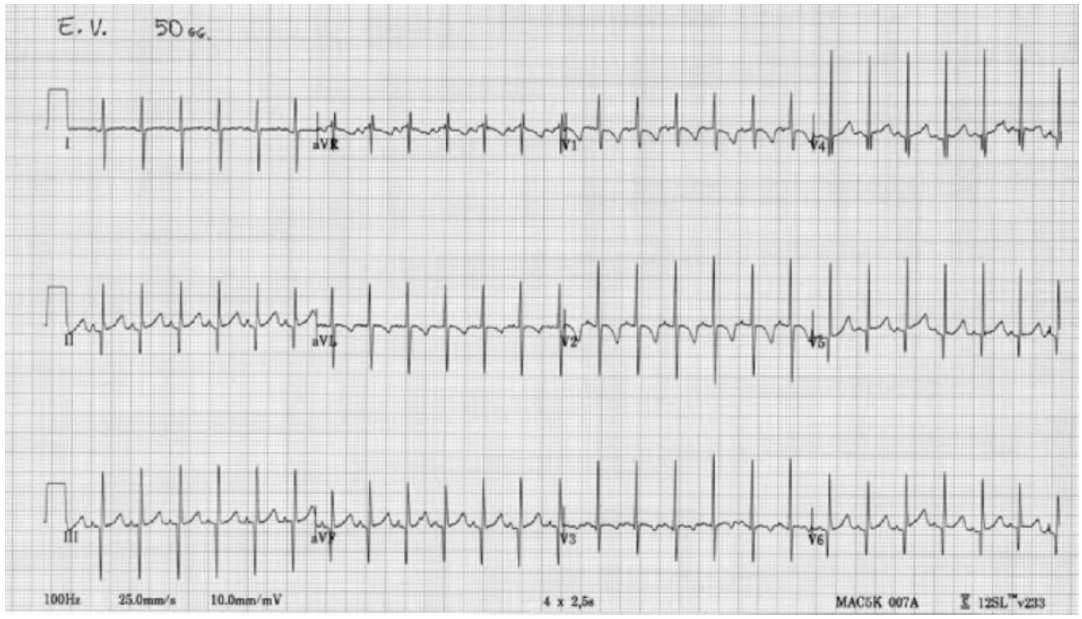

Fig. 1.36 Electrocardiogram recorded of a 50-day-old infant

With regard to the precordial leads (Fig. 1.36), the electrical forces of the ventricles are balanced. In V_1, the R wave of right ventricular depolarization dominates over the S wave of left ventricular depolarization such that R/S > 1. In V_6, the electrical activity of the left ventricle dominates such that there is no S wave of right ventricular depolarization. In this case, the "infant pattern" shows a deep Q wave, which is at the upper limit of the norm for amplitude (10 mm, or 1 mV) in II, III, aV_F and V_6 leads, and is considered a variant of the norm.

The morphology of ventricular repolarization is normal since the T wave is negative in V_1–V_2–V_3 and positive in V_5–V_6. The QRS frontal axis is normal at +95°. This trace shows the "infant pattern", which is congruent with the age of the patient and thus, is normal.

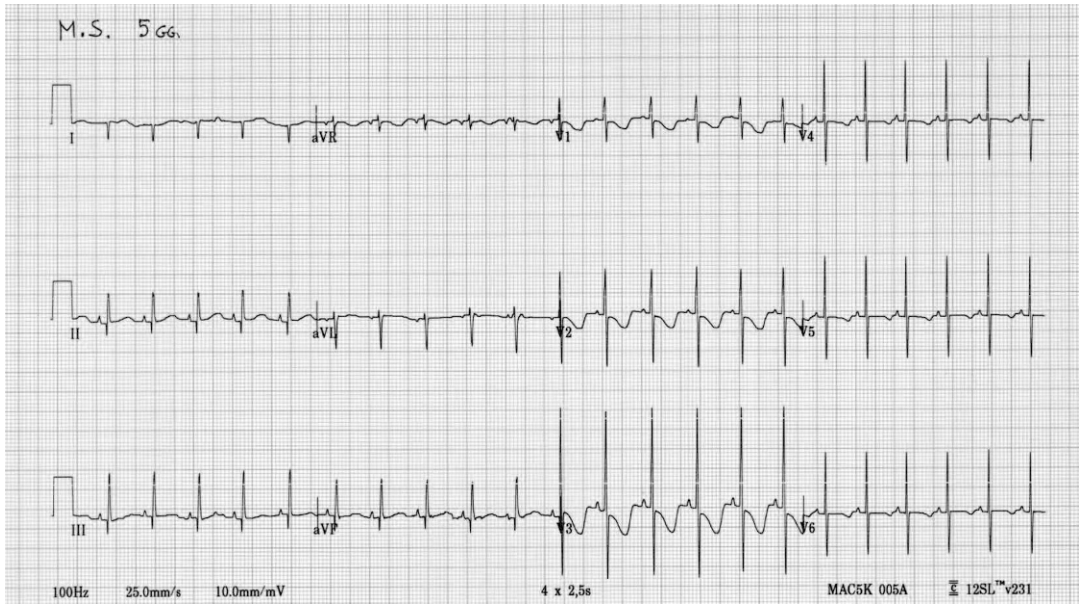

Fig. 1.37 Electrocardiogram recorded of a 5-day-old newborn

For ventricular depolarization, this trace (Fig. 1.37) also presents balanced electrical forces in the ventricles. This is evident in the electrical dominance of the right ventricle in V_1, such that R/S > 1, and the electrical dominance of the left ventricle in V_6, such that R/S > 1. As a variant of the norm, this "infant pattern" can already be present in the first few days of life.

The morphology of ventricular repolarization is normal since the T wave is negative in V_1, V_2 and V_3, and flat/negative in V_5 and V_6. This is a variant of the norm during the first week of life. The QRS frontal axis is right deviated at +120°, which is normal in the first month of life. These elements define this ECG as normal.

Fig. 1.38 Electrocardiogram recorded of a 2-year-old child

In Fig. 1.38, for V_1, the electrical forces of the right ventricle are prevalent such that R/S > 1. In V_6, the electrical forces of the left ventricle are prevalent and the S wave is very small such that R/S > 1. V_1 and V_6 make up a picture of balanced electrical forces, fitting the "infant pattern", which can last up to the age of 3. In this case, the age of the patient is in accordance with the electrocardiographic pattern, so the ECG is to be considered normal.

The morphology of ventricular repolarization (with the T wave negative in V_1–V_2–V_3, and positive in V_5–V_6) and the QRS frontal axis at +50° also contribute to defining this electrocardiogram as normal.

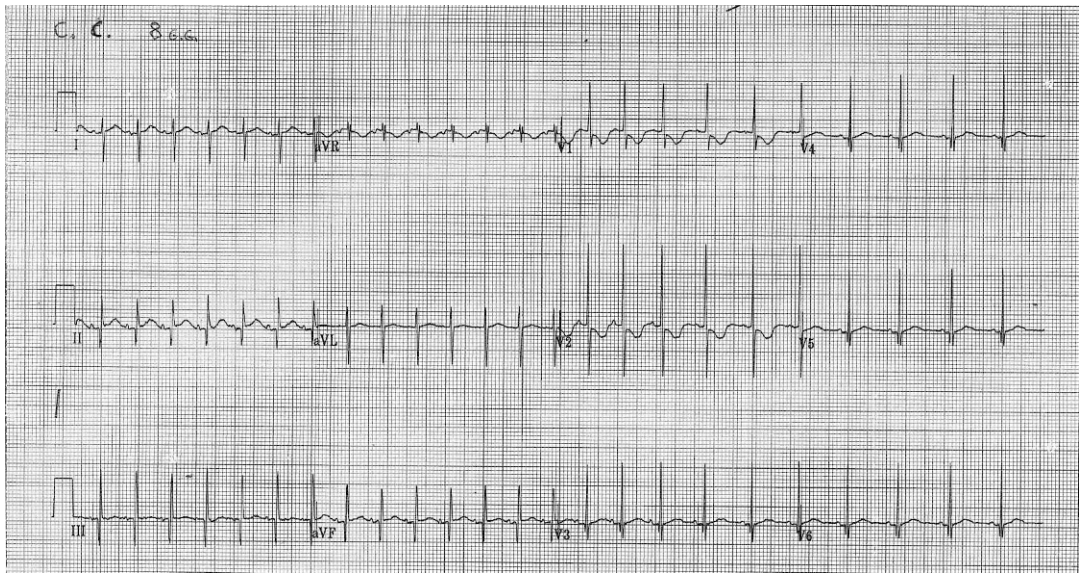

Fig. 1.39 Electrocardiogram recorded of an 8-day-old newborn

Regarding the precordial leads, the electrical forces, in Fig. 1.39, of the ventricles are visibly balanced. In V_1, the electrical forces of the right ventricle are dominant such that R/S > 1. In V_6, the electrical forces of the left ventricle are dominant such that R/S > 1. The deep, 0.5 mV Q wave in II, III, and aV_F leads is within the normal limit of 1 mV and so, is to be considered a variant of the norm.

Ventricular repolarization is normal since the T wave is negative in V_1 and V_2, and positive in V_5 and V_6. The QRS frontal axis is right deviated at +120°, which is normal for newborns (the first month of life). As a variant of the norm, the "infant pattern" can already be present in the first few days of life, therefore this ECG is to be read as normal.

Fig. 1.40 Electrocardiogram recorded of a 3-day-old newborn

The electrical forces of the ventricles are visibly balanced in Fig. 1.40 as well, since R/S > 1 in V_1 and R/S > 1 in V_6. This is in accordance with the "infant pattern" which can already be present in the first few days of life as a variation of the norm.

In relation to the age of the patient (first week of life), the morphology of ventricular repolarization and the +135° right deviated QRS frontal axis fit the normal standards. The T wave is diphasic in V_1 and V_2, negative in V_3 and V_4, and positive in V_5 and V_6. This trace is therefore considered to be normal.

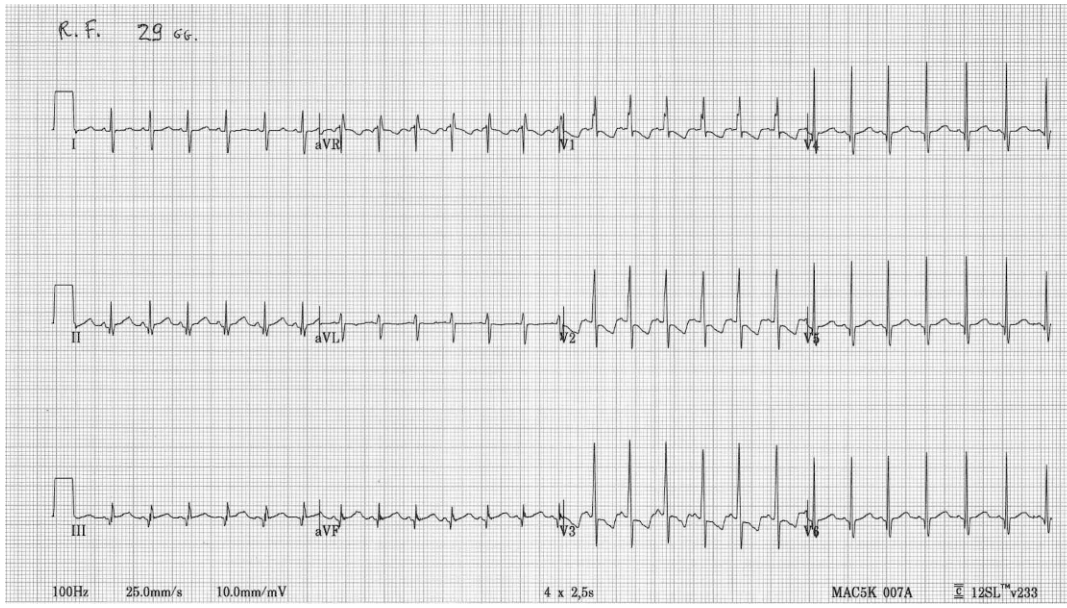

Fig. 1.41 Electrocardiogram recorded of a 29-day-old newborn

In Fig. 1.41, the electrical forces of ventricular depolarization are balanced such that R/S > 1 in V_1 and R/S > 1 in V_6. This "infant pattern" trace shows slightly delayed right intraventricular conduction, which is evident in V_1 through the slurring in the rise of the R wave, and in V_6 through the morphology of the slightly widened S wave.

The morphology of ventricular repolarization (with the T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6) and the QRS frontal axis at +90° is normal. Over all, this ECG is appropriate for the age of the patient and therefore is normal.

1.3 The Adult Pattern

The adult pattern is characterized by prevalent electrical activity in the left ventricle. This ECG pattern is the norm after 2–3 years of life.

This last morphological change that the pediatric ECG goes through is as a direct consequence of hemodynamic and anatomic changes described earlier in this manual, which bring about the typical adult condition of the left ventricular predominance.

Since the electrical forces of the left ventricle dominate, in the V_1 lead the S wave will dominate over the R wave such that R/S < 1. The S wave in V_1 represents the depolarizing electrical activity of the left ventricle. To be considered normal, the voltage of the S wave must be less than 25 mm (2.5 mV). In the V_6 precordial lead, the R wave will dominate over the S wave such that R/S > 1. The R wave in V_6 represents the depolarizing electrical activity of the left ventricle. To be considered normal the voltage of the R wave must be less than 25 mm (2.5 mV) and the S wave (the depolarizing electrical activity of the right ventricle) must have a voltage less than 5 mm (0.5 mV). According to the requisites of the norm, there can never be an exclusive R wave in V_1 (see Table 1.5).

At times, even in the first month of a normal newborn's life, an ECG can show an adult pattern of dominant depolarizing electrical forces of the left ventricle. In these cases, the useful elements in judging a trace as normal are: the voltage of the S wave in V_1, the voltage of the R wave in V_4–V_5–V_6, the morphology of the T wave and the QRS frontal axis.

In terms of the repolarizing electrical activity of the ventricles (the morphology of the T wave), the "adult pattern" is characterized by a positive T wave in V_6 and a negative T wave in V_1–V_2–V_3 up until adolescence (in girls, even later) (Table 1.6). A positive T wave in V_2 and V_3 is, nonetheless, a variant of the norm.

Table 1.5 Adult pattern of ventricular depolarization. Left ventricular prevalence is the norm in the "adult pattern"

QRS – Adult pattern	
In V_1: S wave dominant such that R/S < 1	S wave < 25 mm
In V_6: R wave dominant such that R/S > 1	R wave < 25 mm, S wave < 5 mm
In V_1: R wave never exclusive	

Table 1.6 Adult pattern of ventricular repolarization

T wave – Adult pattern	
In V_1–V_2–V_3: negative	even up to adolescence
In V_6: positive	

Fig. 1.42 Electrocardiogram recorded of a 3-year-old child

In Fig. 1.42, for V_1, the S wave (the electrical forces of the left ventricle) is dominant such that R/S < 1. In V_6, the R wave (again the electrical forces of the left ventricle) is dominant with no S wave of right ventricular depolarization. These elements make up a picture of left ventricular prevalence, which is the norm for the "adult pattern" of ventricular depolarization. The "adult pattern" is normal after the age of 2–3, so this trace is congruent with the age of the patient, thus making it normal.

Together the +30° QRS frontal axis and the morphology of ventricular repolarization (with the T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6) define this ECG as normal.

Fig. 1.43 Electrocardiogram recorded of a 20-day-old newborn

In this trace (Fig. 1.43), one can see the electrical dominance of the left ventricle. In V_1, the S wave is dominant, that is, the depolarizing electrical forces of the left ventricle are prevalent such that R/S < 1. In V_6, the R wave is dominant also meaning the depolarizing electrical forces of the left ventricle are prevalent such that R/S > 1. The voltage of the S wave in V_1 and the R wave in V_6 is normal. Ventricular repolarization is normal with the T wave negative in V_1–V_2 and positive in V_6. The QRS frontal axis is normal at +70°. As is sometimes the case, this "adult pattern" is already present in the first month of life in the absence of organic cardiopathy.

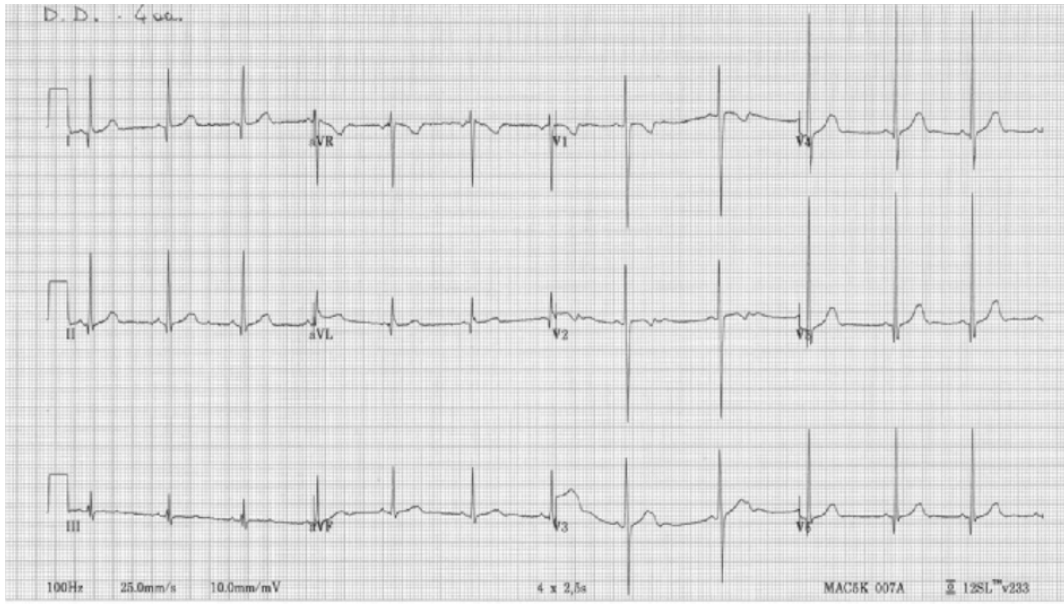

Fig. 1.44 Electrocardiogram recorded of a 4-year-old child

In Fig. 1.44, with regard to the morphology of ventricular depolarization, the electrical prevalence of the left ventricle is visible in the V_1 and V_6 precordial leads. This situation is characteristic of the "adult pattern" and is appropriate for the age of this patient.

Ventricular repolarization is normal with the T wave negative in V_1 and V_2, and positive in V_5 and V_6. The +50° QRS frontal axis is normal after the first year of life. All these elements identify this ECG as normal.

Fig. 1.45 Electrocardiogram recorded of a 20-month-old child

In V_1, the S wave, the electrical forces of the left ventricle, is dominant in that R/S < 1. In V_6, the R wave, which also refers to the electrical forces of the left ventricle, is dominant. These elements constitute a picture of left ventricular prevalence, which is standard in the "adult pattern" of ventricular depolarization. The "adult pattern" is normal after 2–3 years of age and is already present here at 20 months (Fig. 1.45).

Together, the +30° QRS axis and the morphology of ventricular repolarization (with the T wave negative in V_1, V_2 and V_3, and positive in V_5 and V_6) contribute to defining this ECG as normal.

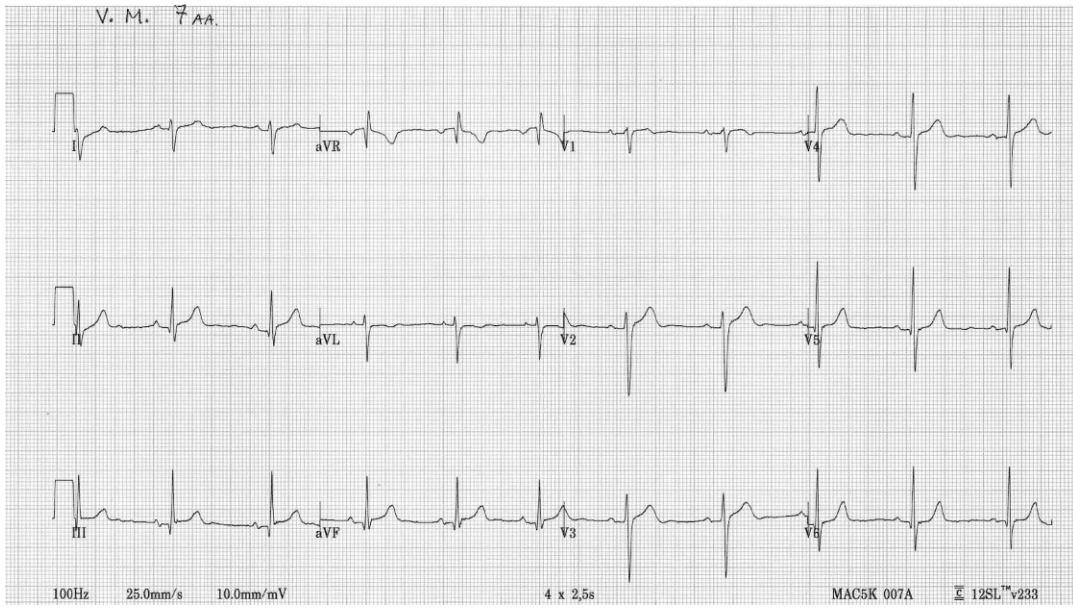

Fig. 1.46 Electrocardiogram recorded of a 7-year-old child

Since the left ventricle has electrical dominance, this trace (Fig. 1.46) fits the "adult pattern" of ventricular depolarization. There is a slight delay of right intraventricular conduction in the QRS morphology in V_1. This is confirmed by the morphology of the S wave in V_6. The still slightly right deviated QRS frontal axis (+110°) is a variant of the norm, as is ventricular repolarization, since the T wave is diphasic in V_1, and positive in V_2–V_3 and V_5–V_6.

Fig. 1.47 Electrocardiogram recorded of a 6-year-old child

In V_1, the S wave, the electrical force of the left ventricle, is dominant such that R/S < 1. In V_6, the R wave is dominant and the S wave of the right ventricular depolarization is absent (Fig. 1.47). This means that, once again, the electrical forces of the left ventricle are prevalent. These elements make up a picture of left ventricular prevalence, which is normal in the "adult pattern" of ventricular depolarization. This "adult pattern" trace is in accordance with the age of the patient since it is the norm after 2–3 years of age.

The +95° QRS frontal axis is normal, as is the morphology of ventricular repolarization, since the T wave is negative in V_1 and V_2, and positive in V_5 and V_6.

Fig. 1.48 Electrocardiogram recorded of a 4-year-old child

In Fig. 1.48, with regard to the precordial leads, in V_1, the S wave, the electrical forces of the left ventricle, is dominant such that R/S < 1, while in V_6, the R wave is dominant such that R/S > 1. This means that, once again the electrical forces of the left ventricle are prevalent. These elements make up a picture of left ventricular prevalence, which is normal in the "adult pattern" of ventricular depolarization, and is congruous for the age of the patient. The +60° QRS frontal axis and the morphology of ventricular repolarization (with the T wave negative in V_1, V_2 and V_3, and positive in V_5–V_6) also contribute to defining this ECG as normal.