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Postnatal Development of the Human Hippocampal Formation

With 23 figures

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To Sofía.

Preface

Ume Eder Bat (A beautiful child) (popular song from Basque folklore)

The aim of this monograph is to introduce the postnatal development of morphological features that are relevant to readers interested in the neurobiology and pathology of the hippocampal formation in terms of the complex phenomena that underlie the progressive anatomical and functional maturation of this brain region. This review focuses on the morphological aspects, while more detailed basic phenomena associated with neuronal maturation—which are undoubtedly also of great interest—are only marginally referred to, although a selection of behavioral and clinical aspects will also be briefly addressed in an attempt to illustrate real situations in different clinical specialties.

The creation of this monograph is justified by the increasing importance and growing awareness shown in recent years of neurodevelopmental disorders in children. This awareness is leading to increasing refinement in clinical examinations of patients that may suffer from different neurodevelopment-related diseases, such as autism, epilepsy, memory disorders, etc. To the best of our knowledge, this work is the first comprehensive description of the postnatal changes in the hippocampal formation in its different constituent fields. Given the growing sensitivity and accuracy of neuroradiological examinations, particularly MRI, we also sought to offer a glimpse at the MRI aspects related to the development of the hippocampal formation in the human infant. Some caution must be exercised here, as our data deal with the anatomo-radiological correlation in ex vivo MRI images taken in fixed, normal human infant brains from routinely obtained necropsies in different hospitals across Spain. In this regard, we would like to show our appreciation of the uninterested help offered by the Pathology and Radiological Services of the Albacete University Hospital Complex (Drs. Atiénzar, Pascual, Cros and Mansilla, as well as their technician Francisca Cortés, who provided immensely valuable help), Drs. Tuñón and García-Bragado from Navarra's Department of Health, Dr. Rábano from Alcorcón Foundation Hospital, and we extend a very special thanks to the Pathology Service of Virgen del Rocío Hospital in Seville, in particular Drs.

Rivas, Chinchón and Fernández, for their tremendous help in providing human infant tissue.

This work is dedicated with kindness to those parents who gave their consent to perform necropsies on their beloved little ones at difficult moments. We hope that they will find comfort in the knowledge that their altruism will improve the health of other children.

Ricardo Insausti

P.S. To my inspiring mentor and friend, Prof. David G. Amaral, whose dedication to autistic children is an example of translational research, from basic science to clinical situations.

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Abstract

The postnatal development of the human hippocampal formation (HF) is subject of increasing interest due to its implication in important pathologies that hamper the normal development of children. In this work, we present a glimpse of the main events that constitute important milestones in the development and shaping of some of the most important psychological capabilities such as autobiographical memory. We analyzed a total of 21 brains ranging from 27 gestational weeks to 14 years. Although we examined some cases in the last trimester of gestation, our description starts at birth, around 40 gestational weeks. Serial sections stained with thionin for Nissl analysis revealed that all fields of the HF were present and identifiable at birth. However, the relative growth of the cortical mantle was much higher relative to the HF. The main structural changes took place during the first postnatal year, in particular in the dentate gyrus and in the entorhinal cortex. At subsequent ages, a growth in size was noted in all components of the HF. This growth was more evident at the body and tail of the hippocampus, as evidenced by measurements of the neuroanatomical series. In addition, we examined in some cases the MRI appearance of the HF at different postnatal ages obtained by post-mortem imaging. MRI neuroanatomical series provided anatomically identified landmarks useful for the MRI identification of different components of the HF during postnatal development.

List of Contents

Abbreviations

A	Amygdala
AC-PC line	Anterior–posterior commissure line
ADHD	Attention-deficit/hyperactivity disorder
AHTA	Amygdalo-hippocampal transition area
ALA	Amniotic liquid aspiration
CA1	CA1 (*cornus ammonis*, Ammon's horn) field of the hippocampus
CA2	CA2 (*cornus ammonis*, Ammon's horn) field of the hippocampus
CA3	CA3 (*cornus ammonis*, Ammon's horn) field of the hippocampus
CD	Caudate nucleus
CHD	Congenital hearth disease
chf	Choroidal fissure
CL	Claustrum
COS	Childhood-onset schizophrenia
cs	Collateral sulcus
DG	Dentate gyrus
DIC	Disseminated intravascular coagulation
DNMS	Delayed-non-matching to sample
EC	Entorhinal cortex
EI	Intermediate subfield of the entorhinal cortex
ELc	Lateral caudal subfield of the entorhinal cortex
EMI	Medial intermediate subfield of the entorhinal cortex
f	Fimbria
fx	Fornix
GA	Gyrus ambiens
GIL	Gyrus intralimbicus
GS	Gyrus semilunaris
H	Hippocampus
HF	Hippocampal formation
hf	Hippocampal fissure
HMD	Hyaline membrane disease
IC	Insular cortex
irs	Intrarhinal sulcus
IQ	Intellectual quotient
its	Inferior temporal sulcus
IVC	Intraventricular communication

las	Lateral sulcus
LGN	Lateral geniculate nucleus
MAP	Microtubule associated protein
MRI	Magnetic resonance imaging
MTL	Medial temporal lobe
mts	Middle temporal sulcus
NIH	National Institutes of Health
ots	Occipito-temporal sulcus
p	Polymorphic cell layer
PAC	Periamygdaloid cortex
PaS	Parasubiculum
PB	Phosphate buffer
PBS	Phosphate buffered saline
PE	Pulmonary edema
PHR	Parahippocampal region
PIR	Piriform cortex
PPH	Posterior parahippocampal cortex
PRC	Perirhinal cortex
PrS	Presubiculum
pul	Pulvinar
PUT	Putamen
RFDH	Respiratory failure by diaphragmatic hernia
rs	Rhinal sulcus
S	Subiculum
SDCO	Sudden death of cardiac origin
SE-HR	Spin eco-high resolution
SMI31	High molecular weight phosphorilated neurofilaments
so	*Stratum oriens* (hippocampus)
sp	Splenium of corpus callosum
sr	*Stratum radiatum* (hippocampus)
ssa	Sulcus semiannularis
sts	Superior temporal sulcus
T	Tesla
TCS	Tissue collection solution
TE	Area TE of Bailey and von Bonin
TF	Area TF of Bailey and von Bonin
TH	Area TH of Bailey and von Bonin
TIR	"Tiempo de inversión-recuperación" in English "Inversion-recovery time"
V	Lateral ventricle
Vc	Sublayer Vc of the entorhinal cortex
w	White matter
WME	Without morphological expression
II	Layer II of the entorhinal cortex
III	Layer III of the entorhinal cortex